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BARK BEETLES ATTACKING LODGEPOLE PINE SLASH UNDER DIFFERENT CUTTING SYSTEMS

Annual Technical Report - 1953.

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ANNUAL TECHNICAL REPORT - 1953

BARK BEETLE POPULATIONS ASSOCIATED WITH SELECTIVELY LOGGED LODGEPOLE PINE

PREFACE:

Results and discussion of this report are presented in three parts:-

Part I deals with the Scolytid populations related to the logging experiment.

Part II deals with the life cycles and biologies of the Scolytidae associated with the lodgepole pine in the experimental area.

Part III deals with the predator-parasite complex associated with the Scolytidae.

During the winter of 1952-53 several phases of the project dealing with distribution and life cycles were analysed. These results were given in the Annual Report 1952.

ANNUAL REPORT - 1953

PART I

TABLE OF CONTENTS

	Page
INTRODUCTION	1
OBJECTS OF INVESTIGATION	1
DESCRIPTION OF REGION	2
DESCRIPTION OF FORESTRY EXPERIMENT	3
MATERIALS AND METHODS	5
Sampling Coverage	5
Field Techniques for Populations	6
Stand cruises 1952, 1953	6
Slash and stump sampling	7
Duff sampling	8
Slash area per block	10
Field Techniques for Study of Environmental Factors	10
Regional temperatures and humidities	10
Block temperatures and humidities	10
Subcortical temperatures of slash and stumps	11
EXPERIMENTAL ANALYSES AND RESULTS	12
A. Bark-beetle Population	12
Endemic population 1951	12
Area of slash per cutting block	18
Block populations - Slash and stumps - 1952	19
Residual stand - 1953	29
B. Effect of Environmental Factors on Populations	32
Block temperatures and humidities	32
Subcortical temperatures	33
Strikes and survival related to subcortical temp.	36
DISCUSSION	38
CONCLUSIONS	43

ANNUAL REPORT - 1953

PART I

INTRODUCTION

The investigation carried out at Strachan, Alberta was undertaken, in part, to determine and explain some of the major factors underlying the variability in concentration of certain bark-beetles in slash under different cutting systems and the effect on the residual stand. The opportunity to carry out this type of investigation was presented to the Calgary Forest Zoology Laboratory in 1952, when the Federal Forest Service initiated studies on selectively cut lodgepole pine, Pinus contorta Dougl., var. latifolia Engelm. in the foothills region of Alberta. This eventually became a cooperative project between the Federal Forest Service, Department of Northern Affairs and ~~Natural~~ National Resources, and the Laboratories of Forest Zoology and Forest Pathology of the Division of Forest Biology.

OBJECTS OF INVESTIGATION

It was anticipated that some form of hazard rating might be evolved when the bark-beetle productivity of each cutting method was determined.

In the final analyses this hazard rating should be interpreted from the number of residual trees in each block struck by bark-beetles originating within the slash of the same block.

The experimental design, while satisfactory for the foresters, did not permit this interpretation because there were not sufficient buffer zones between the cutting blocks.

However, by sampling the slash at the proper intervals, estimates could be obtained of the entering and surviving populations, the latter being available for attack on the residual stands the following year.

The second objective of this phase of the investigation was to determine reasons for the variability, or lack of variability among populations in each cutting block. This involved as complete a study as circumstances allowed of the mesoclimate of the cutting unit, microclimate of the immediate bark-beetle environment, and the parasite-predator pressure.

DESCRIPTION OF REGION

The experimental area of this study is in the region termed by Halliday (1937), the "B. 19 or foot-hills section", and is bordered on the west by the sub-alpine forests of the Rocky Mountains and on the east by the "B. 18 or mixed-wood section" of the boreal forest. The elevation of the whole foot-hills section varies from 3000 to 5000 feet in elevation; that of the experimental area is about 3500 feet.

Halliday (1937) describes the B. 19 region as presenting a rough and broken topography, descending eastward to the plains region in a series of somewhat flat-topped plateaux, much dissected by sharply cut river valleys. The mature soil type is podsolic, overlying mesozoic and tertiary sedimentary bed-rock. The region

is an ecotone condition between the boreal and sub-alpine forests, having been greatly influenced by fire encouraging the growth of lodgepole pine which is subclimax dominant, mixed with white and black spruce. The white spruce, if not prevented by fire, eventually becomes the dominant in the climax formation. Aspen and white birch are next in abundance, with black spruce and larch dominating swampy areas. Balsam fir is replaced by alpine fir. No jackpine occurs.

DESCRIPTION OF FORESTRY EXPERIMENT

The Calgary branch of the Federal Forest Service established nine 10-acre blocks within the experimental area. The design of the project is illustrated in Appendix I. The experimental area is located approximately 20 miles south-west of Rocky Mountain House, Alberta, in a pure stand of even aged (84 years) lodgepole pine. This particular region is very flat with no topographic barriers.

Each block was cut in a different manner. All utilizable material down to a $3\frac{1}{2}$ inch diameter was removed and marketed, the object of the Forestry Department being to determine what happens to the residual stand on each block regarding growth, regeneration, windthrow, insect attack and disease. The individual blocks were treated as follows:

Block I - Heavily thinned from below reducing the number of commercial stems from 664 to 300 per acre. Dominant trees remain.

Block II - Heavily thinned from above reducing the number of commercial stems from 698 to 300 per acre. Sub-dominant and suppressed trees remain.

Block III - Sanitation cut--all dying, deformed and suppressed trees removed.

Block IV - Merchantable trees cut to a diameter limit of 6.5 inches, reducing the number of stems from 697 to 521.

Block V - Uncut control.

Block VI - All merchantable volume removed except 10 seed trees per acre.

Block VII - Clear cut.

Block VIII - Shelterwood cutting, ~~170~~ 70 crop trees per acre ~~removed~~. remain.

Block IX - Patch logging, circular areas 50 feet in diameter clear cut.

Under the supervision of members of the Federal Forest Service, blocks I, II, IV, VI, VIII, and IX were logged in the late fall and winter of 1951-52 by a private operator. Blocks III and VII were logged in the spring and summer of 1952.

It had been anticipated earlier that the entire nine blocks would be included in the entomological investigation. However, the final study included only blocks I, II, IV, VI and VII since it was found that IX did not lend itself properly to the sampling techniques employed. Blocks III and VII were not finished in time to be included.

MATERIALS AND METHODS

Sampling Coverage

Because of the requirements as to detail, it was necessary to restrict the coverage to a minimum which would still meet the demands of statistical analyses.

To obtain the "before" and "after" picture of the bark-beetle populations in the area, sampling was carried out as follows:

(A.) A cruise within the untouched stand carried out in early spring of 1952 supplied figures on the total number of infested trees prior to logging.

Stem analyses of 10 of these infested trees supplied data on the total insects by species, per tree. Duff samples taken below infested trees supplied data on the number of bark-beetles overwintering in the duff.

A cruise carried out in August of 1953 supplied an estimate of the total infested trees within each block, one season after the build-up of populations in the logging debris.

(B.) Sampling of slash and stumps in the early summer and fall of 1952 supplied estimates of the bark-beetle population which had become established in each block in the spring of 1952, and the populations which existed in the fall of 1952. Sampling of slash, stumps, and duff in the early spring of 1953 gave data for determining the bark-beetle population surviving the winter and available for attack on standing trees.

Information on the stand density prior to logging, and the number of residual trees remaining in each block after logging,

was obtained from the Calgary Office of the Federal Forest Service.

Field Techniques for Population Estimates

Stand cruises - 1952, 1953

The 1952 spring cruise for the determination of endemic population required one week and was completed May 19. This involved sampling in two environments, 1) the standing tree, 2) the duff below the tree.

The cruise was carried out as follows:- Two 30 chain strips, running parallel 1 chain apart were cruised using transects ½ chain wide on each strip. Every tree within the strip was examined. All green, fading green, red topped, infested trees were numbered and recorded as to their Dbh, crown classification and general condition. The cruise was carried out in the untouched stand bordering the south side of the experimental area.

Ten of the known infested trees, 5 per strip, were selected randomly and cut down for stem analyses. One lineal foot sample every 3 feet along the stem was debarked with the following data recorded: diameter, number of bark-beetles by species and developmental stage.

On completion of this cruise and stem analyses, 1 foot square duff samples from below 3 infested trees were collected in the manner described below.

- 4 samples adjoining the base of the tree, 1 from each cardinal direction.
- 4 samples halfway between the base and the vertical projection of the crown.
- 4 samples at the vertical projection of the crown.

The duff samples were sent to the field station at Kananaskis where they were run through Berleze funnels.

The 1953 cruise required 8 days and was completed August 11, Three 10 chain strips, 1/2 chain wide, were cruised in blocks I, II, IV, V, VI, VIII. Recorded data was similar to that collected in the 1952 cruise. No stem analyses were made.

Slash and stump sampling

Bark-beetle populations within slash and stumps were determined in permanent plots. All blocks were handled identically: using a staff compass and 100-foot steel tape, ten circular plots 50 feet in diameter were established in each block. Appendix I illustrates the location of the plots. The plots are lettered A to F and W to Z. Within each plot 10 separate foot-long pieces of slash and 5 stumps were marked for sampling.

From each piece of slash and each stump the following information was recorded:

1. Diameter
2. Bark thickness
3. Bark characteristic
4. Position of slash, i.e. aerial or ground
5. Shaded or exposed
6. Direction of main axis of slash
7. Number of strikes by species on each aspect
8. Number of adults, pupae, larvae on each aspect by species
9. Number of predators and parasites on each aspect by species

Slash was debarked using hunting knives. All insect material was preserved in separate vials in 70% alcohol.

Three slash samplings were carried out: July 13 to July 24, 1952; September 4 to September 15, 1952; May 9 to May 16, 1953. Stumps were sampled August 20 to September 2, 1952; May 16 to May 19, 1953.

The stumps were sampled only once during the 1952 season. The most important stump inhabiting insects, Hylastes asper Sw. and Dendroctonus valens Lec. have a slow rate of development, remaining as larvae through the summer and fall. The most common bark-beetle in the experimental area, Ips pini Say, did not attack stumps in significant numbers. It was felt that these points, plus the urgency of other aspects of the 1952 investigation justified a single sampling of stumps.

Duff sampling

The method of handling duff samples, described on page 14 was not satisfactory. It was therefore decided to handle the duff samples collected in the spring of 1953 in a different manner.

A number of collapsible cake boxes, $8\frac{1}{2}$ x $8\frac{1}{2}$ x 4 inches, were purchased from a local supply house. At the Strachan camp these were assembled and reinforced on the outside with sticky paper. A $\frac{3}{4}$ inch circular hole was punched through the back at a height close to the upper level of the duff inside the box. A glass vial was placed over the hole, secured with scotch tape, and at a slight angle downwards. The lid was then taped down. The boxes were kept outside, covered only during rain. Fifty duff samples, from below 5 pieces of marked slash within each of the 10 plots in block I, were collected May 15, 1953. All were placed in the duff boxes.

To establish the efficiency of these boxes, two tests were made using 50 Ips pini adults per test. The adults were obtained from overwintering broods in the slash. Duff was gathered from an area well clear of likely contamination by overwintering bark-beetles. The tests, carried out in May, were started at 8:00 A.M. in the morning when duff temperatures were near 0° C. The inactive adults were placed on the bottom of the boxes, then covered with several inches of duff. The boxes were placed outside, 50 adults per box. They were kept under observation for two weeks but in less than a week, 45 adults had collected in one vial and 43 in the other.

Before the results from the duff samples could be interpreted on a quantitative basis, the distribution into the duff from the slash had to be established. Samples collected below 2 pieces of slash on the 29th and 30th of September 1953, were used to test for the distribution. The duff below these two pieces of slash, one lying in an East-West direction and the other lying in a North-South direction, was sampled as illustrated in Fig. I. Both pieces of slash were heavily infested and some distance from other infested slash. Ten samples each 10 inches square were collected from directly beneath the main axis of the slash. Ten similar samples were collected along each of two parallel lines at right angles to the main axis of the slash. These samples, together with other duff samples collected earlier in September, were placed in cold storage at 32° F. and set up for rearing in the laboratory in January, 1954. Prior to being brought inside, they were inadvertantly subjected to an outside air temperature of -17° F. for several days.

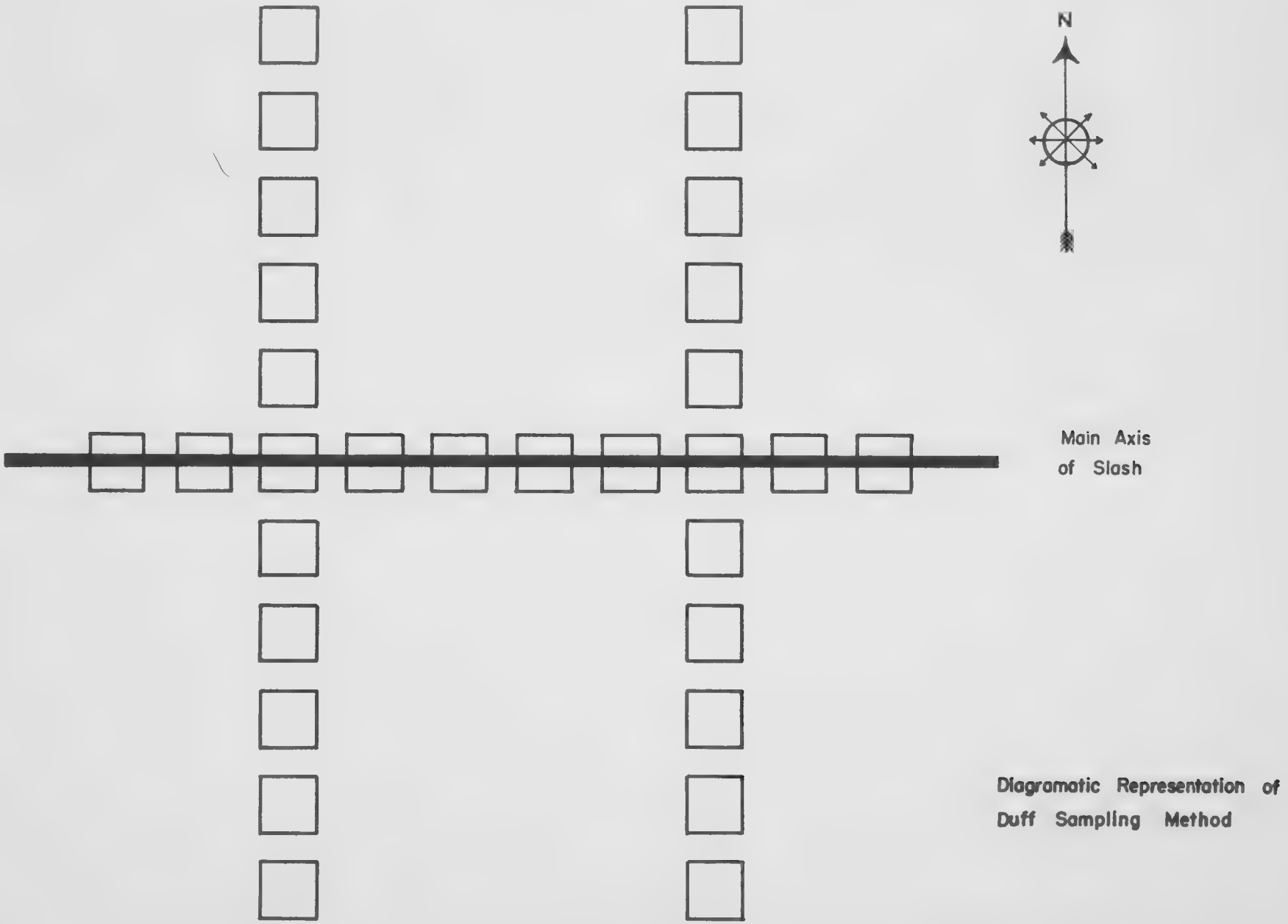


Figure 1

Diagramatic Representation of
Duff Sampling Method

Slash area

To compare bark-beetle populations between blocks on a square foot of bark surface and an acre basis, it was necessary to obtain an estimate of the total bark surface of slash on each block. Lengths and diameters of slash were measured in plots A to F on each block. From these measurements, surface area of slash per plot and per acre were calculated for each block.

Bark areas were determined on each piece of slash and stump using the area equation for the cone or the frustrum of a cone.

Field Techniques for Study of Environmental Factors

Regional temperature and humidities

Daily maximum and minimum temperatures for 8 months of 1952 and 1953 are tabulated in Appendix II. These temperatures are from the Government weather station, located at Rocky Mountain House, 20 miles north-east of the experimental area. The temperatures closely follow the ones taken at Strachan and have been substituted in preference to our own reading because they begin earlier and end later in the season.

Block temperatures and humidities

An effort was made during the summer of 1952 and 1953 to obtain quantitative data illustrating differences in the mesoclimate of each of the blocks. Temperatures and relative humidities were taken 4 times per day in each block from July 28 to August 8, 1952; the times being 8:00 A.M., 12:00 Noon, 4:00 P.M., 8:00 P.M. Two readings were taken for temperature and two readings for R. H. at a marked station in the centre of each 10 acre block. Instruments used were a sling

psychrometer and mercury thermometer. Readings were taken at a height of 4 feet above ground level. To partially allow for the march in daily temperature and R. H. which occurred in the 40 minute interval it took to move through the areas, the order was reversed at each period, i.e. 1, 2, 4, 5, 6, 8; 8, 6, 5, 4, 2, 1, etc. Readings were taken once per day at 4:00 P.M. from August 9 to August 18.

In May, 1953, a hygrothermograph was set up in the shaded block I, and exposed block VI. Shelters were constructed at camp and moved into the blocks. Daily records of the temperature and R. H. at the $3\frac{1}{2}$ foot level were obtained from these hygrothermographs for the period May 18 to September 7, 1953.

Subcortical temperatures

Two stations were established in August 1952, for subcortical temperature readings; one station in an exposed location, the second 200 yards from the first, in a shaded location.

Slash was arranged in the exposed area as follows:

1) Slash 3 inches in diameter

Aerial (18 inches above duff)
2 pieces lying N-S; leads on Top, bottom, East, West
2 pieces lying E-W; leads on Top, bottom, North, South
Ground (lying on duff)
2 pieces lying N-S; leads on Top, bottom, East, West
2 pieces lying E-W; leads on Top, bottom, North, South

2) Tree length from 5 inches at base to tip

Aerial - 2 pieces lying E-W; leads on Top, bottom, North, South at following diameters 4.5-3.5-2.5-1.5-0.5

3) Stumps

2 stumps 6 inches top diameter
2 stumps 11 inches top diameter

Slash was arranged in the shaded area as follows:

1) Slash 3 inches in diameter

Aerial - 2 pieces lying E-W; leads top, bottom
Ground - 2 pieces lying E-W; leads top, bottom

2) Stumps

2 stumps 6 inches top diameter - leads North, South, East, West.
2 stumps 10 inches top diameter - leads North, South, East, West.

Readings were taken with a Rubicon potentiometer; leads into the bark-beetle galleries were number 30 gauge, leads from the potentiometer were number 24 gauge, copper-constantan thermocouple wire.

Leads were placed within bark-beetle galleries on the four aspects of each piece of slash and stumps. The tree length slash had not been struck by Ips so artificial subcortical chambers were made with a bent nail, simulating the bark-beetle galleries. Fig. 3 illustrates diagramatically the lead set-up.

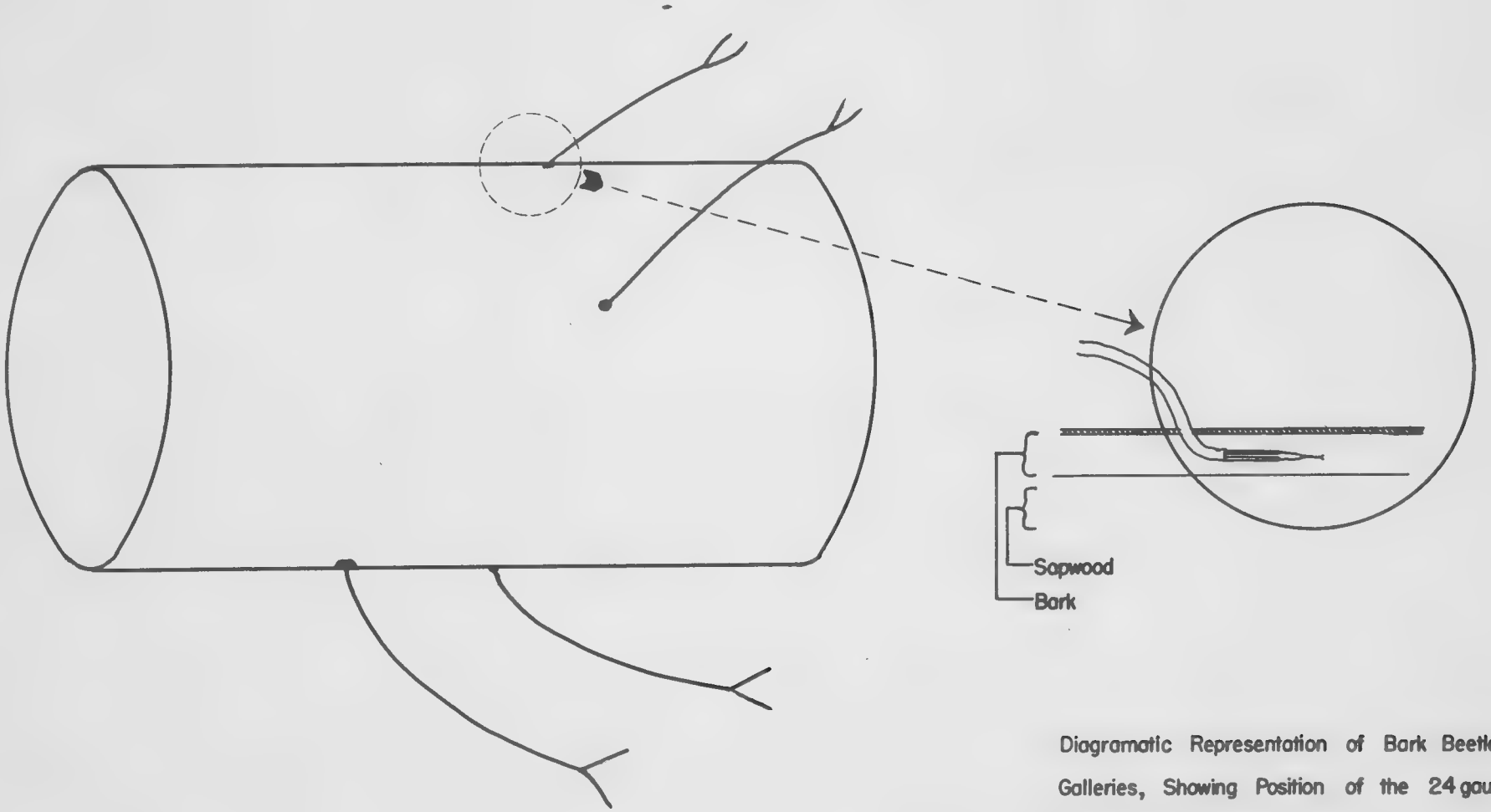
EXPERIMENTAL ANALYSES AND RESULTS

A. Bark-Beetle Populations

Endemic population - 1951

The 1952 spring cruise revealed a stand with 1.7% of the trees infested by bark beetles. The break down into diameter classes on an acre basis is shown in table I. The 1953 cruise is also shown.

Figure 3



Diagramatic Representation of Bark Beetle Galleries, Showing Position of the 24 gauge Thermocouple Leads.

TABLE I - Infested Trees in Untouched Stands - 1952 and 1953.

Dbh Inches	Number of stems in original stand per acre	Infested stems 1952 per acre.	Infested stems 1953 per acre Bl.V
1	0.2	0	0
2	2.1	0	0
3	31.4	1	2.7
4	99.8	2.3	10.0
5	156.3	4.7	14.0
6	166.4	1.7	4.6
7	110.8	0.7	4.0
8	63.6	0.3	0.7
9	23.7	0	0.7
10	9.1	0.3	0
11	2.4	0	0
12	0.9	0.3	0
	666.7	11.3	36.7

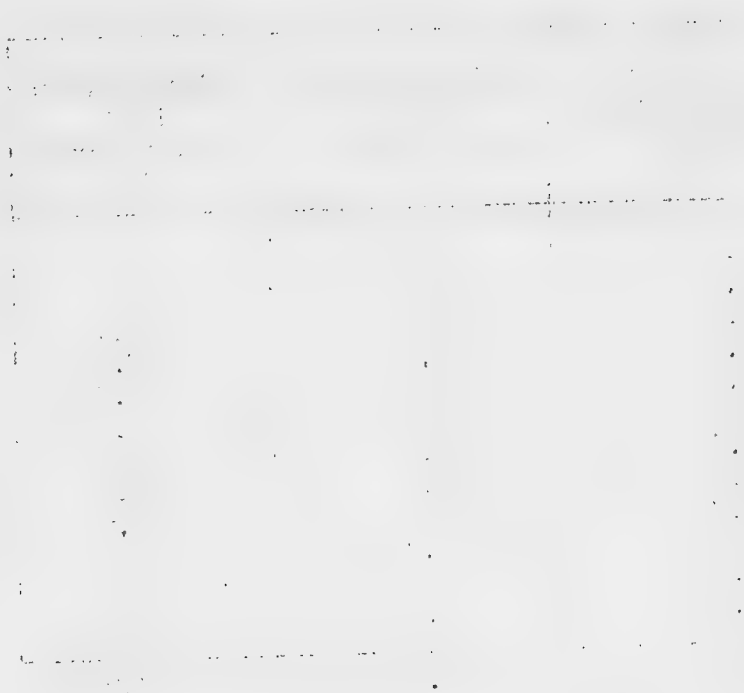
% trees infested:- 1952 - 1.7%

1953 - 5.5%

The 1952 spring cruise was utilized for two purposes. The first to supply an infested tree count per acre before the influx of Scolytidae into the area, the second to supply bark-beetle infested trees for stem analyses. From the stem analyses, the population of adults on a square foot and acre basis could be estimated to give quantitative population figures. This endemic population could then be compared to the population invading the slash both on a square foot of bark surface and acre basis.

The ten debarked trees fell into the following diameter classes: 2 trees in the 4 inch diameter class; 6 in the 5 inch class; 0 in the 6 inch class; 1 in the 7 inch class; 1 in the 8 inch class.

To interpolate the stem analyses data into a total population per tree it was necessary that the total bark surface of each tree per diameter class be known. This could be satisfactorily arrived at only



if the form of the tree was known. This factor was not taken into consideration at the time the stem analyses were being made. Examination of field data in the winter of 1953 revealed available figures for a form factor were present in only the 5 inch diameter class. However the 5 inch class represents a rough mean diameter of the stand in number of stems per acre and number of infested trees per acre. It was felt the most profitable direction to follow was to use the 5 inch tree together with the total number of stems infested per acre in arriving at the estimate of the endemic population.

Trees marked for stem analyses were cut down as close to the ground level as possible. One foot sections every three feet up the stem were debarked, and the information, including diameters, recorded as described earlier. From the series of diameters taken on the 6 stems, Fig. 4 was constructed from which the diameters and heights at any level on the tree could be obtained.

The surface area of the stem was determined every 2 feet using the area equation for the frustrum of a cone. The accumulated area was used to construct Fig. 5, from which could be readily obtained the percentage of bark for any level on the tree, and the number of square feet of bark between any levels.

Results from stem analyses of six trees in the 5 inch diameter class are shown in Table II.

Figure 4

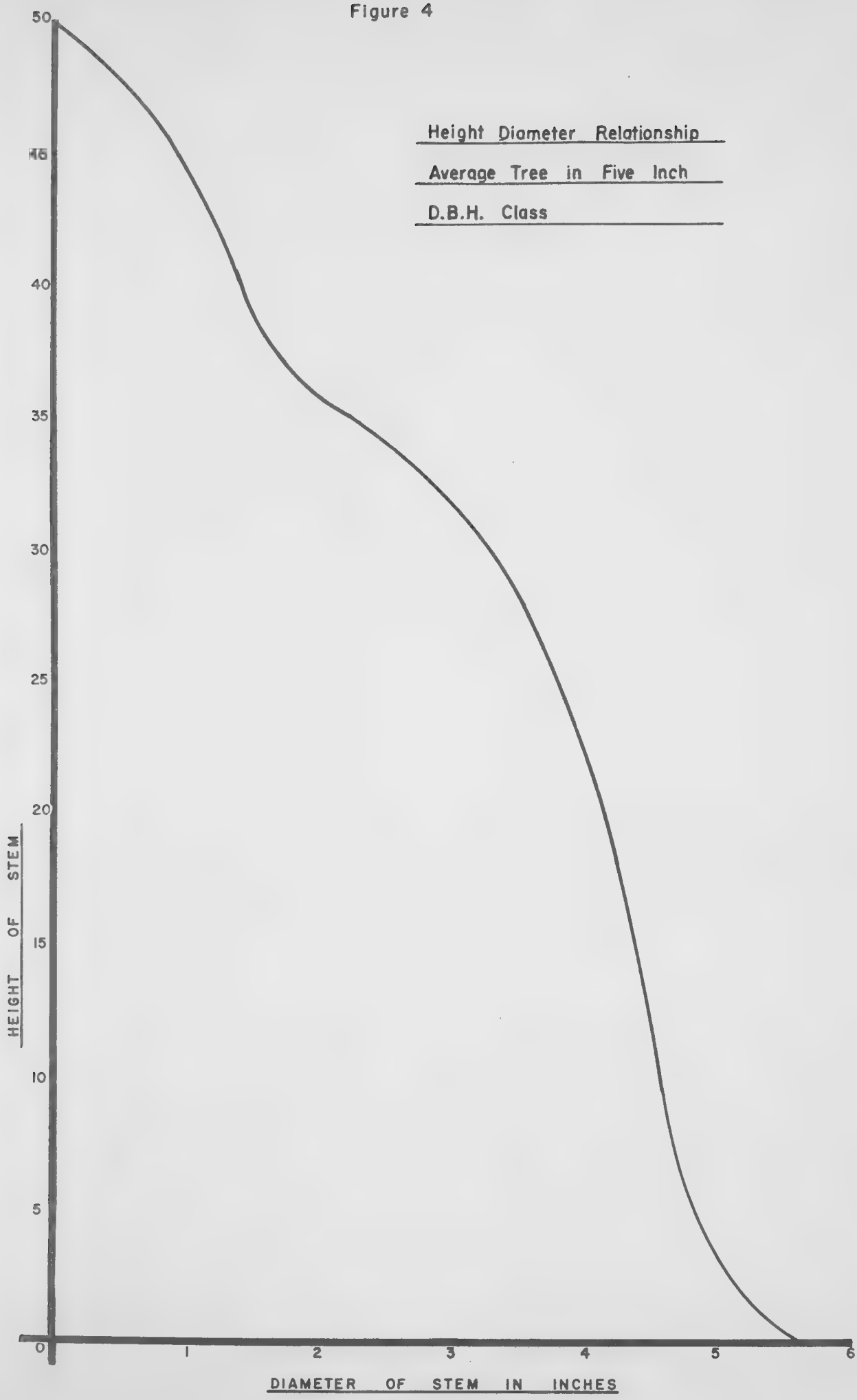

Height Diameter Relationship
Average Tree in Five Inch
D.B.H. Class
50
45
40
35
30
25
20
15
10
5
0
HEIGHT OF STEM
1
2
3
4
5
6
DIAMETER OF STEM IN INCHES

Figure 5

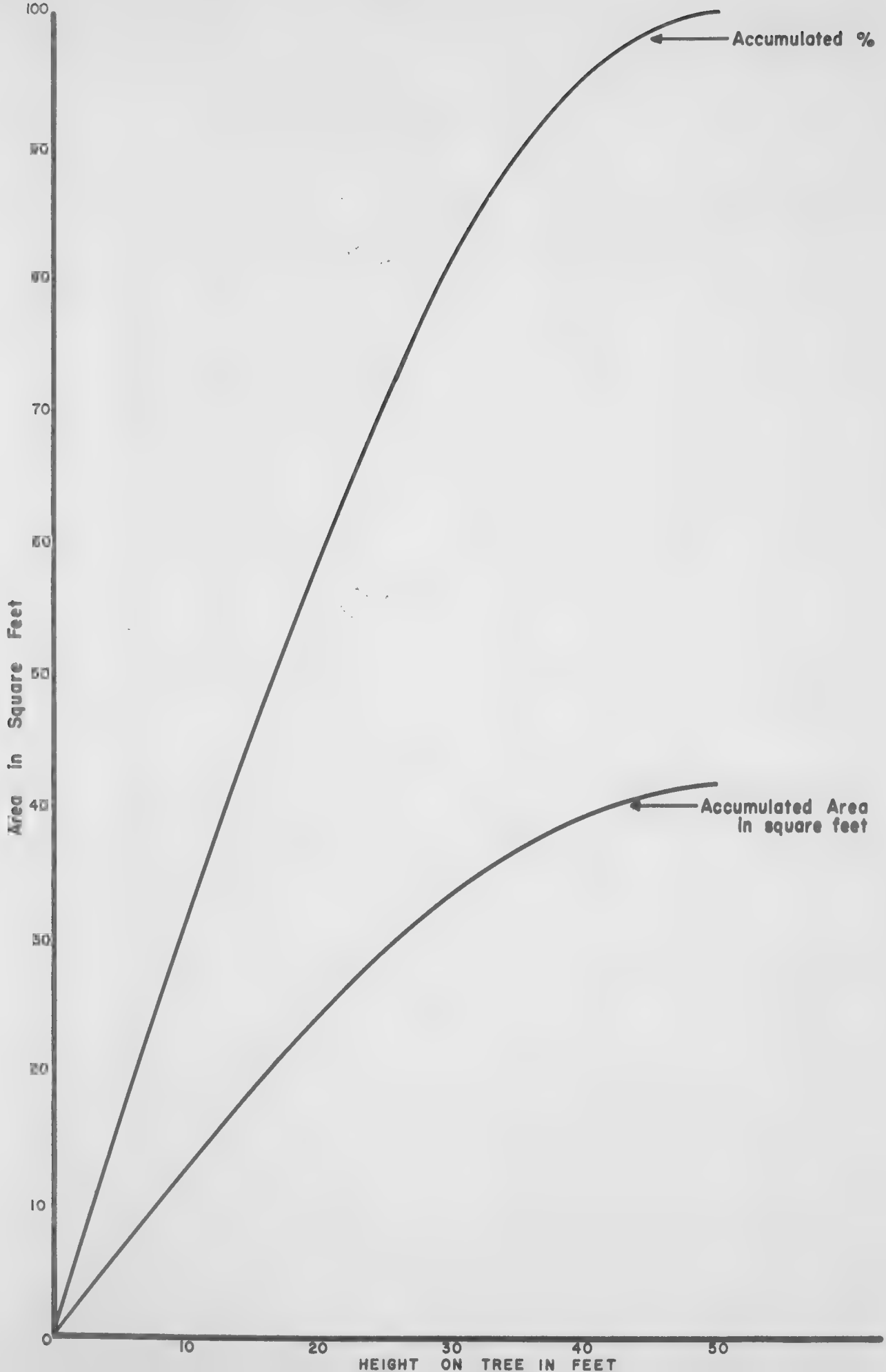

100
90
80
70
60
50
40
30
20
10
0
Area in Square Feet
Accumulated %
Accumulated Area
in square feet
10
20
30
40
50
HEIGHT ON TREE IN FEET

TABLE II - Number of Bark Beetles in Stem Analyses Samples from Six Trees in 5 inch Diameter Class

Ht. on Stem	Tree #	Ips pini Adults	Ips pini Larvae	Ips guildi Adults	Ips guildi Larvae	Pityogenes knechteli Adults	Pityogenes knechteli Larvae	Orthotomicus sp. Adults	Orthotomicus sp. Larvae
	504	(16)	12	0	0	0	0	0	0
1 ft.	508	2	0	10	25			0	0
	511	1	1(3)	0	0	negative		0	0
A	513	7	0	3	0			8	0
	523	29	0	0	0			0	0
	530	22	0	0	0			0	0
	504	(5)	2	2	11	ø	ø	0	0
4'	508	2	0	4	2			0	0
	511	1(12)	1	0	0			0	0
B	513	22	0	0	0	negative		14	0
	523	31	0	0	0			0	0
	530	10	0	0	0			0	0
	504	2	0			ø	ø	0	0
8'	508	0	0					0	0
	511	1(1)	0	negative		negative		0	0
C	513	15	0					6	0
	523	33	0					0	0
	530	12	0					0	0
	504	1	0			ø	ø	0	0
12'	508	0	0					0	0
	511	(3)	0					0	0
D	513	15	0	negative		negative		3	0
	523	34	0					0	0
	530	4	0					5	0
	504	1	0			ø	ø	0	0
16'	508	0	0					0	0
	511	0	0					0	0
E	513	2	0	negative		negative		2	0
	523	31	0					0	0
	530	4	0					2	0
	504	0	0			7	0	0	0
20'	508	0	0					0	0
	511	1	2	negative				0	0
F	513	0	0					11	0
	523	4	0					0	0
	530	0	0					0	0
	504	(3)	0			ø	ø	0	0
24'	508	0	0					0	0
	511	0	0	negative		negative		0	0
G	513	0	0					4	0
	523	4	0					0	0
	530	0	0					0	0
	504	0	0			2	4	0	0
28'	508	0	0			0	0	0	0
	511	1(3)	0	negative		0	0	0	0
H	513	3	0			0	0	5	0
	523	0	0			0	0	0	0
	530	0	0			cont'd.		0	0

Cont'd.... TABLE II - Number of Bark Beetles in Stem Analyses Samples from Six Trees in 5 inch Diameter Class.

Ht. on Stem	Tree #	*Ips pini* Adults	*Ips pini* Larvae	*Ips guildi* Adults	*Ips guildi* Larvae	*Pityogenes knechteli* Adults	*Pityogenes knechteli* Larvae	*Orthotomicus* sp. Adults	*Orthotomicus* sp. Larvae
	504	0	0			2	2		
	508	0	0			0	0		
32'	511	0	0	negative		0	0	negative	
	513	0	0			0	0		
I	523	0	0			0	0		
	530	0	0			0	0		
	504					4	5		
36'	508					0	0		
	511					0	0		
J	513	negative		negative		0	0	negative	
	523					0	0		
	530					0	0		
	504					6	10		
40'	508					0	0		
	511					0	0		
K	513	negative		negative		0	0	negative	
	523					0	0		
	530					0	0		
	504					14	7		
44'	508					0	0		
	511					0	0		
L	513	negative		negative		0	0	negative	
	523					0	0		
	530					0	0		
48' M		negative		negative		negative		negative	

Four species of bark beetles were found. The total adults per tree was determined by species as follows: e.g. *Ips pini*

Total adults from 6 trees = 295
Average per tree = 49.2
Adults found to 32' level up the stem
Total area debarked in sample = 8 one foot samples = 10.34 sq.ft.
32 foot level on stem contains 35.2 sq. ft. bark
Average adults per debarked area = $\frac{49.2}{10.34}$ = 4.8 per sq. foot bark.
Total adults per tree = 35.2 x 4.8 = 170

The populations per tree for the other species found were calculated the same as for Ips pini, i.e. Ips guildi = 22.1; Pityogenes knecktelí = 268.6; Orthotomicus sp. = 255.

Several of these totals need further adjustment before the populations on an acre basis can be estimated; of the 6 trees analysed, only 3 contained Ips guildi. It is assumed of the entire infested trees in this diameter class, that this same ratio would hold i.e. 3/6. Referring to Table I, of the 4.7 trees per acre infested in the 5 inch class, the number of trees containing Ips guildi would amount to 3/6 times 4.7 or 2.35 trees per acre; number of trees containing Pityogenes knecktelí would amount to 1/6 x 4.7; Orthotomicus would amount to 2/6 x 4.7; Ips pini would amount to 6/6 x 4.7.

The population estimate within standing trees on an acre basis is presented in Table III, using information shown in Table I. (See population in duff p.18)

TABLE III - Endemic Bark Beetle Population Per Acre in Standing Trees

Diam.Class in inches	No.Infested Stems per acre	Total Adults per acre of Standing Trees			
		Ips pini	Ips guildi	Pityogenes knecktelí	Orthotomicus
3	1	170	11.1	44.8	25
4	2.3	391	25.4	103.0	57.5
5	4.7	799	52.0	210.6	117.5
6	1.7	289	18.8	76.2	42.5
7	0.7	119	7.8	31.4	17.5
8	0.3	51	3.3	13.4	7.5
10	0.3	51	3.3	13.4	7.5
12	0.3	51	3.3	13.4	7.5
	11.3	1921	125	506	283

Duff sample results from below 3 infested trees in May 1952 are given in Table IV.

TABLE IV - Ips Pini Adults From Duff Samples
Beneath Standing Trees

Tree #	Location of Sample	Adjacent to Stem				Half way between base & vertical projection of crown				Vertical projection of crown				Total
	Direction	N.	E.	S.	W.	N.	E.	S.	W.	N.	E.	S.	W.	N.E.S.W.
1	All Ips pini Say	0	1	2	6	0	0	2	1	0	1	0	0	13
2		0	0	0	0	0	0	0	0	0	0	0	0	0
3		1	1	0	3	2	2	0	0	1	1	0	2	13

Average number of adults per tree = 8.7
Average number of adults per sq. foot duff = $\frac{8.7}{12}$

Total area within 4' radius of tree base = 50.3 sq. ft.
Total adults within duff per tree = $50.3 \times \frac{8.7}{12}$

Number of infested trees per acre = 11.3
Adults within duff per acre = $11.3 \times 50.3 \times \frac{8.7}{12} = 412$

Total adult Ips pini within untouched stand per acre:
in trees = 1921
in duff = 412

The endemic population estimate of Ips pini would therefore amount to 2333 per acre.

Area of slash and stumps per block

The 6 plots per block, in which slash and stumps were measured, amounted to a 2.7% sample of the total ground area of each block. Table V summarizes the results showing the square feet of bark surface per block.

TABLE V - Bark Surface Area of Slash
and Stumps per acre

Block	Total Surface Area of slash in sq.ft. on 6 plots	Surface Area of Slash in sq.ft. per acre	Stumps per acre	Surface Area in sq.ft. of stumps per acre
I	1989	7367	230	322
II	2491	9226	285	513
IV	623	2307	185	352
VI	3324	12300	396	634
VIII	3160	11704	362	905

Block populations

Slash and stumps

A summary of the spring and fall samples (100 pieces of slash) in each block, and the spring 1953 sample in block I is shown in Table VI (see page 20).

Bark-beetles found in 30 stumps per block are summarized in Table VII. Predators and parasites associated with the bark-beetles are summarized in Table VIII.

TABLE VIII - Total Larval Parasites and Predators in 30 Stumps per Block

	Block I	Block II	Block IV	Block VI	Block VIII
Dolychopodidae	90	71	107	78	122
Coenomyidae	8	8	3	6	21
Hymenophera	15	12	11	2	9
Cleridae	8	8	3	6	21

To convert the 100 lineal foot slash sample into the total population per block the following procedure was used.

a. All samples were totalled.

b. The mean number of insects per sample determined.

c. The mean diameter of slash sampled in each block was determined and from this the total square feet of bark.

d. Total population estimates per block were obtained by multiplying total bark surface by the average insects per square foot.

TABLE VI - Bark Be

Block #		Ips pini					Orthotomicus					Pityogenes					Polygraphus		Hymenoptera					
		Strikes	A	P	L	Total	Strikes	A	P	L	Total	Strikes	A	P	L	Total	Strikes	A	A	P	L	Total	Diptera	Cleridae
1952	Spring	370	780	388	2123	3291	28	52	-	427	479	18	28	1	205	234	12	43	1	45	71	117	23	55
I	Fall	368	1674	233	-	1907	12	40	-	0	40	39	79		232	311	10	21		101	68	207	95	27
1953	Spring	288	64		3	65	10	7	-	17	22	8	10		22	32	8	10		67	48	115	20	3
1952	Spring	188	391	313	925	1629	4	6	-	-	6	19	21	2	250	273	6	4	3	32	40	75	4	10
II	Fall	217	1491		42	1533	2	7	-	-	7	15	43		205	248	2	3		39	45	84	60	6
1952	Spring	60	169	70	102	341	42	38	-	87	125	-	-	-	-	-	1			5	20	25	7	6
IV	Fall	94	194		2	196	12	13	-	-	13	18	27		99	126				7	3	10	15	7
1952	Spring	198	1000	554	662	2216	10	10	-	-	10	21	10	3	342	355				43	72	115	4	14
VI	Fall	269	1377		8	1385	12	13	-	-	13	8	65		234	299				3	14	17	55	9
1952	Spring	217	672	340	743	1755	7	6	-	-	6	53	85	3	609	697	2		2	28	21	51	6	16
VIII	Fall	192	933		20	953	..	-		-		15	22		424	446				8		8	23	3

TABLE VII - Bark Beetles in 30 Stumps
Per Block - August 1952

Hylastes asper Sw.

Block	STRIKES N.	E.	S.	W.	ADULTS N.	E.	S.	W.	LARVA-PUPA N.	E.	S.	W.	Total Strikes	Total Insects
I	26	48	28	24	22	46	36	12	489	373	296	291	126	1565
II	10	10	6	12	6	7	3	5	365	264	268	526	38	1444
IV	27	28	28	28	79	99	14	8	1079	761	1033	1104	111	4477
VI	10	7	8	10	0	1	14	27	178	101	138	237	35	695
VIII	11	14	9	15	4	2	8	10	240	287	198	233	49	982
					Orthotomicus sp.									
I	19	28	40	18	40	42	122	54	79	123	178	137	105	775
II	9	10	37	24	25	47	289	224	3	8	59	73	80	728
IV	12	14	32	34	52	97	136	124	11	13	18	28	92	479
VI	32	54	102	74	195	364	699	368	41	53	119	168	262	2007
VIII	48	77	140	89	222	380	728	499	27	43	103	78	354	2080
					Dendroctonus valens Lec.									
I		2	4	4		1	2	2		5	67	23	10	100
II	2	2	2	2	1	1	3		42	14	29	79	8	169
IV			1	1			2	1			95		2	98
VI	3	2		3	4			4	144	105	14	127	8	398
VIII	10	6	2	8	6	4	1	10	103	170	127	341	26	762
					Ips pini Say.									
I		10	4	10	8	21	25	75	15		3	29	24	176
II	1		1	3		8	16				3		5	27
IV		3	3	4		21	6	10					10	37
VI	5	5	11	7	14	10	47	18	2	2		2	28	95
VIII	29	35	25	32	150	169	179	241	10	21	33	1	121	804

Table IX illustrates the mean diameters of the 100 lineal foot samples in each block.

TABLE IX - Mean Diameter of Marked Slash per Block

	Mean Diameter at Slash	Standard Deviation
Block I	3.4	0.209
II	3.4	0.202
IV	3.4	0.114
VI	3.7	0.149
VIII	3.8	0.119

Stump populations were obtained in the manner described above for slash. Hylastes asper and D. valens larvae are found mainly in the bark area below the duff level and no figures are available on the bark surface of this portion. Populations of these two species were obtained using total stumps per acre rather than surface area.

Block population estimates are summarized in Tables 10 to 16.

TABLE X - Total Popu[illegible]

Block #	Sq.ft.Slash per acre	Sq.ft.Stumps per acre	Adults/sq. ft. slash	Adults/sq. ft. stump	Adults/acre slash	Adults/acre stumps	Total adults per acre	All stages/ sq.ft.Slash	All stages/ sq.ft.Stump	All stages /acre slash	All stages /acre stump
Spring I	7367	322	8.8		64,830			36.9		271,842	
Fall			18.8	3.1	138,499	998		21.4	4.2	157,654	1,352
Spring II	9226	513	4.4		40,594			18.3		168,836	
Fall			16.8	0.4	154,997	205		17.2	0.5	158,687	257
Spring IV	2307	352	1.9		4,383			3.8		8,767	
Fall			2.2	0.6	5,075	211		2.2	0.6	5,075	211
Spring VI	12300	634	10.3		126,690			22.8		280,440	
Fall			14.2	1.9	174,660	1205		14.3	2.0	175,890	1268
Spring VIII	11704	905	6.7		78,650			17.5		204,820	
Fall			9.3	9.8	108,847	8869		9.5	10.7	111,188	9683

TABLE XI - Total Population Estimates of Pityogenes knechteli in Slash - 1952

Block #	Sq.ft.Slash per acre	Adults per sq.ft.slash	Adults per acre	All stages per sq.ft.slash	All stages per acre
I Spring	7367	0.3	2210	2.6	19154
Fall		0.9	6630	3.5	25784
II Spring	9226	0.2	1845	3.1	28600
Fall		0.5	4513	2.8	25833
IV Spring	2307	0	0	0	0
Fall		0.3	692	1.4	3229
VI Spring	12300	0.1	1230	3.7	45510
Fall		0.7	8610	3.1	38130
VIIISpring	11704	0.85	9948	6.9	80757
Fall		0.22	2575	4.5	52668

TABLE XIII - Total Population Estimates of Dendroctonus valens in Stumps - 1952

Block #	Stumps per acre	Adults per stump	All stages per stump	Adults per acre	All stages per acre
I	230	0.2	3.3	46	759
II	285	0.2	5.6	70	1596
IV	185	0.1	3.3	18.5	610
VI	396	0.3	13.3	119	5267
VIII	362	0.7	25.4	253	9195

TABLE XII - Tot

Orthotor cus Sp.

Block #	Sq.ft.slash per acre	Sq. ft. stumps/acre	Adults /sq. ft. slash	Adults /sq. ft. stumps	Adults/acre Slash	Adults/acre Stumps	All stages /sq.ft.slash	All stages/ sq.ft.stump	All stages /acre slash	All stages /acre stump	Total all stages /acre
I Spring	7367	322	0.6		442		5.4		3978		
Fall			0.4	6.1	2947	1964	0.4	18.5	294.7	5957	6252
II Spring	9226	513	0.06		554		0.06		554		
Fall			0.06	10.8	554	5540	0.06	13.5	554	6925	7479
IV Spring	2307	352	0.4		923		1.4		3230		
Fall			0.15	7.2	346	2534	0.15	8.4	346	2957	3303
VI Spring	15911	634	0.1		1230		0.1		1230		
Fall			0.1	28.6	1230	18,132	0.1	35.2	1230	22,320	23550
VIII Spring	11704	905	0.06		702		0.06		702		
Fall			0	24.4	0	22,082	0	27.7	0	25,069	25069

TABLE XIV - Population Estimates of *Hylastes asper* in Stumps - 1952

	Ave. Diam.	Ave. Ht.	Stumps per acre	Adults per stump	All stages per stump	Adults per acre	All stages per acre
I	7.4	8.8	230	3.9	52.2	897	12,006
II	7.6	10.7	285	0.7	48.1	199	13,709
IV	8.9	10.0	185	7.0	149.2	1295	27,602
VI	7.7	10.0	396	1.4	23.2	554	9,187
VIII	8.2	13.9	362	0.8	32.7	289	11,837

TABLE XV - Population Estimates of *Enoclerus sphegeus* Larvae in Slash and Stumps - 1952

Block	Sample	Sq.ft. slash per acre	Sq.ft. stump per acre	Clerids /sq.ft. slash	Clerids /acre slash	Clerids /sq.ft. stump	Clerids /acre stump
I	Spring	7367	322	0.62	4568		
	Fall			0.3	2210	0.19	62
II	Spring	9226	513	0.11	1015		
	Fall			.07	646	0.15	77
IV	Spring	2307	352	.07	161		
	Fall			.08	185	0.5	176
VI	Spring	12300	634	0.14	1722		
	Fall			.09	1107	0.1	63
VIII	Spring	11704	905	0.15	1756		
	Fall			0.03	351	2.8	2534

TABLE XVI - Population Estimates of Dipterous and Hymenopterous Predators and Parasites in Slash and Stumps - 1952.

Block	SLASH				STUMP			
	Diptera /sq.ft. bark	Diptera /acre	Hymenoptera /sq.ft. bark	Hymenoptera /acre	Diptera sq.ft. Stumps	Diptera /acre	Hymenoptera /sq. ft. stump	Hymenoptera /acre
I Sp.	0.3	2210	.1.3	9577				
Fall	1.1	8104	2.3	16944	2.1	676	0.6	183
II Sp.	0.04	369	0.8	7380				
Fall	0.7	6458	0.9	8303	1.6	821	.14	72
IV Sp.	0.08	185	0.3	692				
Fall	0.16	369	0.1	231	1.9	668	0.2	70
VI Sp.	0.41	5043	1.2	14760				
Fall	0.57	7011	0.2	2460	1.4	887	.05	32
VIII Sp	0.06	702	0.5	5852				
Fall	.23	2692	.08	936	1.6	1448	.12	109

Spring 1953 slash sampling in Block I (100 pieces) produced the following:-

Ips pini adults - 64 alive, 55 dead
Orthotomicus adults 7
larvae 17
Pityogenes adults 10
larvae 22
Hymenoptera (larvae and pupae) 116
* Diptera (Cocoons) 20

* Diptera pupate mainly within the fibrous inner bark; this habit increased difficulty of detection which likely resulted in a number being missed.

Spring 1953 stump sampling (2 per plot A-F) produced:-

Hylastes asper adults - 3
larvae - 1353 alive, 11 dead
Dendroctonus valens adults - 6
larvae - 215

It should be noted that 12 stumps do not give a sufficiently large sample to use as an estimate of block populations. The average per stump in the spring population is not indicative of the block population. Winter mortality, judging by the number of dead larvae is very light.

The estimate of the spring 1953 populations are shown in Table 17.

TABLE XVII - Population estimates in slash of Block I - May - 1953

Species	Number per sq. ft. bark surface		Number per acre
Ips pini	(Duff population 1.96)(see pg.29)		13997
	Living adults	0.7	5157
	Dead adults	0.6	
Pityogenes knecktelei	All stages	0.35	2578
Orthotomicus	All stages	0.24	1768
Hymenoptera	Larvae & Pupae	1.30	9577
Diptera	Cocoons	0.22	1621

Results from the 50 duff samples collected in Block I, May 1952, produced the following:-

25	produced	0	adult	Ips	1	produced	4	adult	Ips
12	"	1	"	"	1	"	5	"	"
7	"	2	"	"	1	"	8	"	"
2	"	3	"	"	1	"	14	"	"

The results obtained from the duff samples collected on September 29 and 30, as illustrated in Fig. 1, indicate Ips drop directly into the duff from the slash above. Forty-four adults emerged from these duff

samples of which 42 came from duff directly below the main axis of the slash.

Because Ips drop directly into the duff from the slash above, a square foot of duff was then considered to be analogous with a square foot of bark. The 50-10 inch square duff samples, totalling 32 square feet of duff, produced a total of 63 adults Ips. The overwintering duff population in block I was therefore determined as follows:

Average Ips per square foot of duff = $\frac{63}{32}$ = 1.96

Total duff population below 7367 square feet of slash = 1.96 x 7367 = 13,997 per acre.

Total Ips population in duff and slash in block I, May 1953 = 13997 + 5157 = 19154 per acre

Residual stand - 1953

Results from the block cruises carried out in August 1953 are summarized in Tables 18 to 22.

TABLE XVIII- No. of Infested trees per acre in Block I - 1953

Dbh	Number Stems Original Stand	Infested in Original Stand 1952	Residual Stand 1953	Residual Infested 1953
1	0.2	0	0.2	0
2	2.1	0	2.1	0
3	31.4	1	31.4	0
4	99.8	2.3	5.8	2.6
5	156.3	4.7	39.6	2.6
6	166.4	1.7	77.2	1.3
7	110.8	0.7	81.7	1.3
8	63.6	0.3	61.1	0.6
9	23.7	0	26.2	0
10	9.1	0.3	8.6	2.0
11	2.4	0	2.4	0
12	0.9	0.3	0.1	0.6
	666.7	11.3	336.5	11

% trees infested: 1952 = 1.7
1953 = 3.3

TABLE XIX - No. of Infested Trees Per Acre in Block II - 1953

Dbh	Number Stems Original Stand	Infested in Original Stand 1952	Residual Stand 1953	Residual Infested 1953
1	0.2	0	0.2	0
2	2.1	0	2.1	0
3	31.4	1	31.4	2/ 1.3
4	99.8	2.3	11.5	2/ 1.3
5	156.3	4.7	56.5	4/ 2.6
6	166.4	1.7	90.1	3/ 2.0
7	110.8	0.7	85.5	1/ 0.6
8	63.6	0.3	49.7	0
9	23.7	0		
10	9.1	0.3		
11	2.4	0		
12	0.9	0.3		
	666.7	11.3	327.1	7.8

% trees infested: 1952 = 1.7
1953 = 2.4

TABLE XX - No. of Infested Trees Per Acre in Block IV - 1953

Dbh	Number Stems Original Stand	Infested in Original Stand 1952	Residual Stand 1953	Residual Infested 1953
1	0.2	0	0.2	0
2	2.1	0	4	0
3	31.4	1	16	2/ 1.3
4	99.8	2.3	119	9/ 2.6
5	156.3	4.7	205	4/ 2.6
6	166.4	1.7	174	8/ 5.3
7	110.8	0.7	3	0
8	63.6	0.3		
9	23.7	0		
10	9.1	0.3		
11	2.4	0		
12	0.9	0.3		
	666.7	11.3	521.2	11.8

% trees infested: 1952 = 1.7
1953 = 2.3

TABLE XXI - No. of Infested Trees Per Acre in Block VI - 1953

Dbh	Number Stems Original Stand 1952	Infested Original Stand 1952	Residual Stand 1953	Residual Infested 1953
1	0.2	0	0	
2	2.1	0	0	
3	31.4	1	0	* 1.3
4	99.8	2.3	0	* 5.3
5	156.3	4.7	0	* 6.7
6	166.4	1.7	0.1	
7	110.8	0.7	0.4	
8	63.6	0.3	1.7	
9	23.7	0	4.0	
10	9.1	0.3	2.5	
11	2.4	0	0.7	
12	0.9	0.3	0.5	
	666.7	11.3	9.9	13.3

% trees infested: 1952 = 1.7

* These trees should have been removed in the logging.

TABLE XXII - No. of Infested Trees Per Acre in Block VIII - 1953

Dbh	Number Stems Original Stand 1953	Infested Original Stand 1952	Residual Stand 1953	Residual Infested 1953
1	0.2	0	0	
2	2.1	0	0	
3	31.4	1	0	0.6
4	99.8	2.3	0.1	1.3
5	156.3	4.7	0	
6	166.4	1.7	4.0	
7	110.8	0.7	16.0	
8	63.6	0.3	18.5	
9	23.7	0	14.4	
10	9.1	0.3	8.2	
11	2.4	0	3.5	
12	0.9	0.3	0.6	
	666.7	11.3	65.3	1.9

% trees infested: 1952 = 1.7
1953 = 2.9

B. Effect of Environmental Factors on Populations

Block temperatures and relative humidity

Analyses of temperature and relative humidities taken in 1952, failed to reveal significant differences between blocks. Table 23 gives a summary of the readings for 10 days taken between 8 A.M. and 9 A.M. Tables 24 and 25 show results from analyses of variance tests on both temperatures and relative humidities.

TABLE XXIII - Temperatures and Relative Humidities Between 8 and 9 A.M. for 10 days

	Aug.	15	16	17	18	19	20	21	22	23	24
Block I	Temp.	68	70	72	61	63	65	63	71	70	60
	R. H.	54	48	38	84	60	66	55	64	64	58
II	Temp.	71	69	72	63	57	66	63	72	71	56
	R. H.	37	47	39	79	82	53	55	61	52	82
IV	Temp.	72	63	72	70	56	66	65	70	68	59
	R. H.	28	69	34	55	88	44	56	64	67	72
V	Temp.	70	63	70	67	56	62	62	70	62	57
	R. H.	36	69	53	58	88	79	69	68	79	82
VI	Temp.	72	70	70	68	57	63	60	73	68	59
	R. H.	28	48	44	54	82	64	68	57	54	78
VIII	Temp.	73	70	69	69	57	63	63	73	69	60
	R. H.	29	51	47	55	82	64	64	57	55	48

TABLE XXIV - Analysis of Variance in Block Temperatures

Source of Variation	Sum of Squares about mean	Mean Square	D. f.
Between Blocks	47	9.4	5
Random Variation Within Blocks	2164	40	54
Total	2211		59

F. = 0.23

TABLE XXV - Analysis of Variance in Block Relative Humidities

Source of Variation	Sum of Squares about mean	Mean Square	D. f.
Between Blocks	997	199	5
Random variation within blocks	14063	260	54
Total	15060		59

F = 0.76

Differences between block mesoclimates must exist, especially between block I (shaded) and block VI (exposed). Failure of collected data to reveal this has been attributed to:

1. The $3\frac{1}{2}$ foot level too high above duff, shutting out effects of surface radiation.
2. One station per block insufficient.
3. Techniques not critical enough.
4. Number of overcast cool days masked the differences which are apparent on clear warm days.

Figure 6 illustrates copies of hygrothermograph sheets covering the second week in July 1953. During this unusually warm clear week, differences between the exposed block VI and the shaded block I are apparent. Greater differences may have been recorded had the hygrothermographs been below the $3\frac{1}{2}$ foot level.

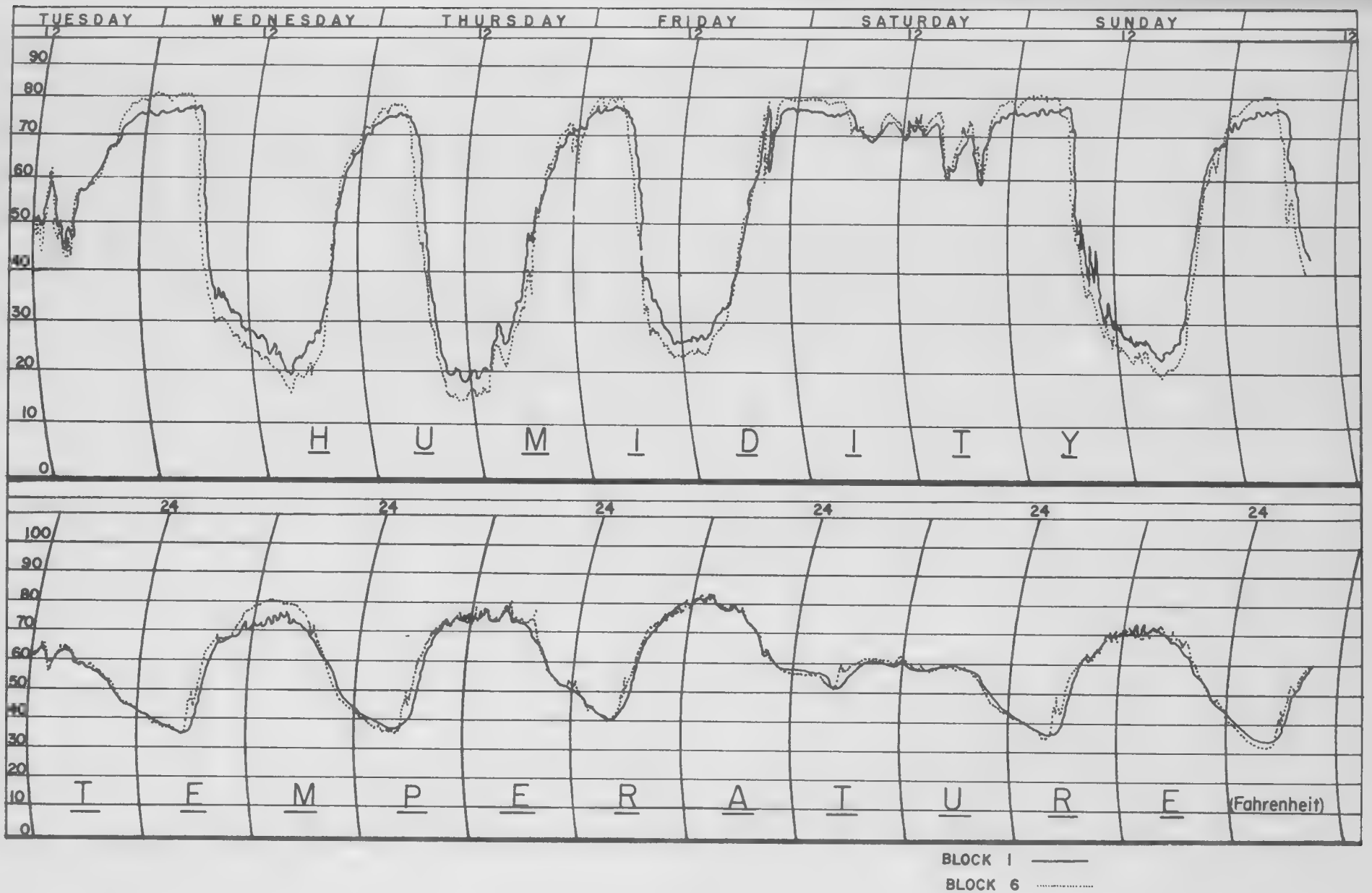

TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
12
90
80
70
60
50
40
30
20
10
0
HUMIDITY
24
100
90
80
70
60
50
40
30
20
10
0
TEMPERATURE (Fahrenheit)
BLOCK 1
BLOCK 6

Figure 6

Subcortical temperatures

TABLE XXVI - Mean Subcortical Temperatures of Slash at Air Temperatures of 23° - 25° C. - Exposed Location

	Aerial Slash		Ground Slash	
	Top	Bottom	Top	Bottom
Mean	44.6° C.	27.5	47.5	22.0
Standard Dev.	4.8	3.4	6.6	4.1
Variance	23	11.5	43	17.2
Number	12	12	12	12

Table 26 summarizes the temperatures recorded for top and bottom aspects of 3 inch slash lying on the ground and 12 inches above the ground. All means are significantly different above $t_{.01}$ level except aerial top and ground top.

TABLE XXVII - Mean Subcortical Temperatures of Aerial Slash Lying E. - W. and N. - S. at Air Temperatures of 23° - 25° C. - Exposed Location

	Aerial Slash				Ground Slash			
	North	South	East	West	North	South	East	West
Mean	27	45.5	32.3	34.9	27.7	51.7	34.5	46.7
Standard Dev.	3.1	4.8	4.1	3.7	4.1	3.3	6.1	7.6
Variance	9.6	23.1	17.2	13.4	16.6	11	36.7	57.2
Number	6	6	6	6	6	6	6	6

Table 27 presents results from aerial slash lying in an east-west position and a N-S position. Significant differences above $t_{.01}$ level exist between all means except for the following:-

Aerial top versus aerial south

Aerial bottom versus aerial north

Aerial bottom versus aerial east

Ground top versus ground south

Ground top versus ground west

Aerial north versus ground north

Aerial east versus ground east

TABLE XXVIII - Mean Subcortical Temperatures at Various Diameters of 2 Tree-Length Pieces of Slash With Air Temperatures 23° - 25° C.

Diameter (inches)	4.5	3.5	2.5	1.5	0.5
Top	36.5	36.6	38.5	36.8	34.4
Bottom	28.7	28.1	30.0	29.9	30.4
North	26.6	27.4	28.5	29.8	30.6
South	36.8	37.0	36.8	36.5	33.3

Table 28 gives the average temperatures over a 5 day period when air temperatures were between 23-25° C. Lodgepole pine, being a thin barked species, exhibits very little difference in bark thickness over the main section of the stem. No significant differences in temperatures due to diameter occurred.

TABLE XXIX - Mean Subcortical Temperatures of Two Stumps - 3 day period - Exposed Location at Air Temperatures of 23° - 24° C.

	North	East	South	West
Mean	27.6	29.7	44.5	37.7
Standard Deviation	1.74	2.4	2.4	5.8
Variance	3.04	5.7	5.8	33.6
Number	6	6	6	6

There was some indication that subcortical temperatures varied with the size of the stump but the basic data for smaller stumps (6 inches top diameter) became mixed and has not been used. Table 29 gives mean temperatures for two 10 inch stumps taken on 3 separate days. All means in this table are significantly different above $t_{.01}$ level.

TABLE XXX - Mean Subcortical Temperatures of Aerial and Ground Slash - Shaded Location with Air Temperatures of 23° - 24° C.

	Aerial Top	Aerial Bottom	Ground Top	Ground Bottom
Mean	23.5	21.3	24.5	15.9
Standard Deviation	0.40	0.43	1.9	2.0
Number	8	8	8	8

Slash in shaded area, as illustrated in Table 30, tends to follow air temperature except the bottom aspect in the ground slash, which follows duff temperature.

TABLE XXXI - Mean Subcortical Temperatures of 2 stumps Shaded Location with Air Temperatures 22° - 23° C.

	North Aspect	South Aspect
Mean	21.9	21.1
Standard Deviation	1	1.3
Number	8	8

Table 31 presents the mean subcortical temperatures within 2 shaded stumps during 4 days. As in shaded slash, subcortical temperatures follow the air temperature.

Strikes and survival related to subcortical temperature

To determine if Ips preferred certain sectors of slash, data was analysed from the two blocks with the greatest extremes in exposure. Block I was the least disturbed, block VI was considered as practically clearcut for our purposes, there being only 10 trees per acre in the residual stand. All slash lying in an east-west direction, within the 3-3.9 inch diameter class was included in this analyses. Table 32 summarizes the strikes per sample on each aspect of aerial slash.

TABLE XXXII - Mean No. Ips Strikes on Various Slash Aspects in Exposed and Shaded Blocks

	Block I				Block VI			
Block I	Top	Bottom	North	South	Top	Bottom	North	South
Mean	0.9	1.0	0.8	1.1	0.2	0.8	1.0	0.4
Standard Dev.	1.2	1.2	1.1	1.0	0.5	1.2	1.1	0.7
Variance	1.4	1.4	1.3	1.0	0.3	1.5	1.2	0.5
Number = 27					n = 36			

No significant differences occur in the shaded block I, while all means differ except Top and South in the exposed block VI.

TABLE XXXIII - Mean No. Ips pini (All Forms) on Various Slash Aspects

	Block I				Block VI			
	Top	Bottom	North	South	Top	Bottom	North	South
Mean	3.5	7.2	4.0	3.4	0.4	3.8	2.7	1.2
Standard Dev.	5.2	10.4	5.4	5.8	2.1	9.5	5.4	4.4
Variance	27.5	107.6	29.3	33.7	4.3	89.5	29.6	19.0
Number	27				36			

Table 33, tabulated from the fall samples shows the survival or production associated with various aspects of the slash in the shaded block and the exposed block. In the exposed blocks, top and south aspects had fewer survivors, in addition to fewer strikes, as illustrated in Table 32.

TABLE XXXIV - Mean No. Strikes Ips pini on Aerial Slash Lying E.W. and N.S.

	Block I		Block VI	
	E-W Slash	N-S Slash	E-W Slash	N-S Slash
Mean	4.5	3.6	2.6	2.2
Standard Deviation	3.2	3.5	2.2	2.5
Variance	10.1	12.1	4.9	6.3
Number	23	19	31	24

While the E-W slash appeared to have a higher number of strikes than N-S slash, analyses indicated the differences were not significant.

TABLE XXXV - No. of Ips Strikes and Ips Survival (All Forms) on Various Aspects of Ground Slash Lying E.W. and N.S.

	Slash lying E - W								Slash lying N - S							
	Strikes				Survival all forms				Strikes				Survival all forms			
	Top	Bottom	N.	S.	Top	Bottom	N.	S.	N.	S.	E.	W.	N.	S.	E.	W.
Block I 6 pieces of slash	2	1	1	5	1	5	8	11	2	1	2	3	5	8	10	16
	1	2	1	1	3	47	4	1	2	2	4	2	6	7	13	16
			2	2	6		7		1	1	2	3	4	2	2	
			4				21		1	3	1		1	8		
											1					
	3	3	8	8	10	52	40	12	6	7	10	8	16	25	25	44
Block VI 5 pieces of slash	2	1	2	1	0	0	0	0	0	2	2	0	0	9	0	0
		1		2												
		1		2												
		1														
	2	4	2	5	0	0	0	0	0	2	2	0	0	9	0	0

Only a small portion of the slash in each block lay on the ground, 11 pieces were marked as samples in block I and II in block VI. The total strikes and survival is shown in table 35. There was insufficient data on ground slash to test against populations in aerial slash. It is interesting to note that practically no progeny were recovered from ground slash in the exposed block, VI.

DISCUSSION

The area in which this investigation was carried out formed a part of a larger region notable for its great similarity of forest cover. Prior to logging operations it was comparatively uniform throughout in respect to site conditions, stems per acre, diameter classes, etc., so it may be assumed the bark-beetles were similar with respect to species and abundance. By spring, 1952, however, the environment in each block had been changed by various types of cutting carried out the preceding winter.

Roughly there were three contrasting environments among the five blocks investigated. Block IV was well shaded but contained very little slash. Blocks I and II were shaded but contained large volumes of slash. Blocks VI and VIII were exposed and contained large volumes of slash.

The distribution of Scolytidae throughout the experimental area showed some variation by species in respect to concentration within certain blocks. The newly established Scolytid population within the logging debris and stumps was higher in all blocks than the original endemic population. It is unlikely however that these new populations

were the result of mass invasions from distant sources but rather an infiltration from surrounding stands.

The total populations, including adults, pupae, and larvae of each species in July and in Sept. of 1952, are illustrated in Appendix 3 to 7.

A previous analyses, based on strikes by Ips pini per lineal foot of sample, indicated a relationship between concentration of this species and degree of exposure of the slash. This condition is not a apparent when total populations per acre based upon surface area of slash are analysed. The two extreme blocks in respect to degree of exposure are Blocks I and VI. Within these two blocks populations on an acre basis are alike. (See Appendix 3) Similarly for blocks II and VIII. Block IV appeared unable to compete with the other blocks due to the limited quantity of slash laid down in that block.

The second Scolytid associated with the slash, Pityogenes knecktelí Sw., did not appear on the area in large numbers. Its presence among the various blocks appeared to be little influenced by the degree of exposure in the blocks. (See Appendix 4)

Orthotomicus, while confined mainly to the stumps, appeared to concentrate more in the exposed heavily cut blocks. No stumps in any block were saturated with this species, so it would seem improbable the flying adults in the spring were attracted to the greater source of food when more than enough stump areas were present in all blocks. (See Appendix 5) The behavior of the two preceding species, Ips and Pityogenes, did not appear to be unduly influenced by the slight differences in air temperature and humidity illustrated in Figure 6, it is assumed Orthotomicus reacted the same. While no figures are avail-

able, it could be that light was the critical factor in attracting this latter species to the exposed blocks.

Two Scolytids; Hylastes asper Sw., and Dendroctonus valens Lec., were found associated with stumps, for the most part near the base and in subcortical regions of large roots. These two species exhibited opposite preferences; Hylastes being more prevailent in shaded blocks and D. valens more prevailent in exposed blocks.

Hylastes was by far the most common stump inhabiting insect. The high population in Block IV is attributed to the large stumps resulting from a diameter limit cut. The average stump diameters, (the mean of individual top and bottom diameter) in each block was as follows: block I - 7.4 inches; block II - 7.7 inches; block IV - 9.0 inches; block VI - 7.7 inches; block VIII - 8.2 inches.

The most numerous bark-beetle on the area was Ips pini, and information gathered on the role of predators and parasites is associated for the most part with this Scolytid. During the course of the field work in 1952, it was assumed that Ips pini broods in the exposed blocks VI and VIII would suffer extremely heavy mortality due to the effect of direct solar radiation. On the other hand, broods in the shaded blocks, and especially block I, would have a high survival rate. The role of predators and parasites was not at the time considered to be too important.

Within the exposed blocks there was considerable mortality in the slash due to the high subcortical temperatures. (See Tables 26 - 29) The temperature alone was not the critical factor but rather the drying out of the bark resulting from high temperature. Thicker barked stumps were subjected to temperatures as high as slash, but

brood survival did not vary between aspects. In the case of stumps, drying out of subcortical regions was much slower than occurred in the slash. However, within the slash, mortality was not as high as expected due to the selective behavior of the bark-beetles in establishing their broods on the shaded sides. (Tables 32 - 35) Within block I, this selective behavior was not apparent because temperatures on various aspects seldom went much higher than air temperatures. (Tables 30 - 31)

Judging from analyses of predator and parasite populations, illustrated in Appendix 8 to 10, there appears to have developed a situation favoring the surviving broods in the exposed blocks VI and VIII. Within these blocks, very low populations of predators and parasites were established. Survival of these species was low due to similar factors as those affecting the Scolytidae. Parasitic Hymenoptera in particular appear to have suffered considerable mortality in exposed blocks. Dipterous predators, while increasing slightly between spring and fall samples were not near as abundant in the exposed blocks in the fall. Clerid larvae, for the most part Enoclerus sphegeues Fab. did not become well established in the exposed blocks.

The drop in total brood population of Ips pini within block I during the summer is attributed mainly to large numbers of parasites and predators.

Ips pini appeared to suffer the least mortality in block II. This block was partially shaded, and also contained a small population of predators and parasites.

The larval environment of Hylastes and Dendroctonus was not subjected to extreme temperatures and desiccation. Bark temperatures applying more directly to these two species are shown in Part II

of this report, dealing with biologies. It is sufficient to report here that hi n temperatures are not a factor in larval mortality of the above two species when the larvae are working below the duff level. The greatest pressure on developing broods of these two was due to competition between adjacent broods and from the larvae of a large root weevil, Hypomolyx sp. Mortality in developing broods, due to the above two factors was not determined but must have been considerable. Examination of stumps frequently revealed clusters of Hylastes or Dendroctonus larvae cut off from further food by the deep engravings and solidified tube-like Hypomolyx galleries.

Due to the lateness in arriving on the area in the spring of 1953, only one block was sampled to determine overwintering mortality and spring populations. This sample was carried out in block I. During the first week of May there had been 4 days with air temperatures above 70° F. Temperature remained cool however during the course of the sampling, beginning May 10. While the duff still retained frost, it was probable that some of the overwintering slash adults may have emerged during the previous warm spell and moved from the area. The condition of the duff, however, in this shaded block most likely prevented escape of adults from that environment.

The spring 1953 population within block I is shown in Table 17. While the population of Scolytids in slash was considerably higher than the endemic population in the spring of 1952, the large drop from the 1952 fall population in part may be attributed to adult escape from the slash during the earlier warm spell. Approximately 50% of the adult Ips in slash were dead. No figures are available on duff mortality. The habits of clerids and dipterous predators made the spring count of these species somewhat difficult. The clerids overwinter in the duff while the Diptera spin cocoons commonly

in the bast layer of the bark, making detection difficult.

Within stumps, broods of Hylastes and Dendroctonus remained little changed, the number of larvae killed by winter temperature being insignificant.

Results from the 1953 cruise of each block in August are shown in tables 1, 18-22. The residual stands in lightly cut blocks showed an increase in total trees infested. Block V, which was not disturbed, had a 100% increase. However, in all blocks, the per cent of infested trees was so low as to constitute no hazard in 1953.

At the time this cruise was carried out Hylastes broods, and in many cases Dendroctonus, were still in the late larval or pupal stage. Their effect on the residual stand could not be determined. A cruise in 1954 will determine whether these two species constitute a hazard to the residual stand.

CONCLUSIONS

1. Varying amounts of slash, if occurring in large volumes, attracts about equal numbers of Ips bark-beetles, regardless of degree of exposure of that slash.
2. Summer mortality to broods in exposed slash is attributed mainly to dessication of subcortical regions resulting from high bark temperature.
3. Survival of broods in exposed slash is increased by the selective behavior of the adult beetle in establishing the broods in more shaded portions.

4. Survival of broods in exposed slash is increased also by the low predator and parasite populations within exposed blocks.
5. Summer mortality in shaded blocks is attributed to the abundance of predators and parasites in those blocks.
6. Parent adult Ips attacking slash in shaded blocks do not show a selective behavior regarding aspect of the slash where broods are established.
7. There is some evidence to indicate exposed slash on the ground produces fewer bark-beetles than exposed aerial slash. Subcortical temperatures of ground slash are higher than subcortical temperatures of aerial slash in all aspects but the bottom.
8. Where slash was partially shaded, and predator and parasite populations were low, as in Block II, there was not a high summer mortality of bark-beetle broods.
9. The direction in which slash lies does not effect the bark-beetle productivity of that slash.
10. Orthotomicus populations were higher in exposed blocks.
11. Dendroctonus valens Lec. populations were higher in exposed blocks.
12. Hylastes asper Sw. populations were higher in shaded blocks.
13. Most blocks showed an increase in number of standing trees, attacked, but the percentage of infested trees remained much below that which would constitute a dangerous condition during 1953.

With reference to lodgepole stands of this type existing on the east slope of the Rocky Mountains, the following conclusions appear to be justified:-

1. Cutting to a diameter limit of 7 inches in this type of stand does not produce enough slash suitable for bark-beetle increase

to consitute any serious hazard.

2. Clear cutting or treatments approaching this, resulting in large volumes of slash, create the greatest bark bettle hazard. Although solar radiation causes high mortality of bark-beetle broods, the beetles tend to select unexposed parts of the slash. Moreover, environmental conditions on clear-cut areas are not conducive to the build-up of bark-beetle parasites and predators.

3. Selection cut systems resulting in large volumes of slash but retaining a high percentage of shade from the residual canopy, produce an abundance of bark-beetles which are not appreciably reduced by solar radiation. However, environmental factors on such areas favor the build-up of bark beetle parasites and predators, greatly reducing the hazard to residual stands.

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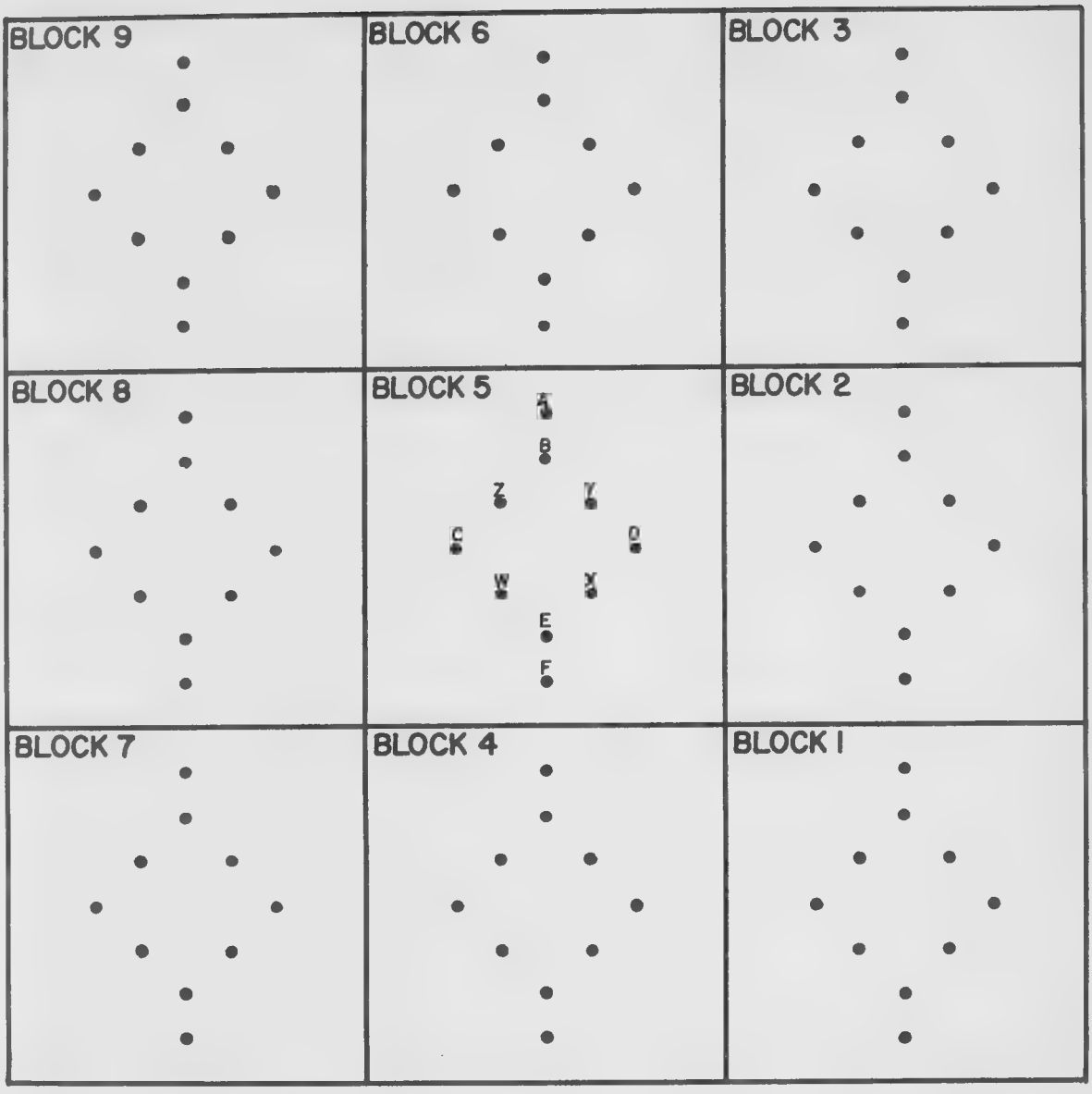
APPENDIX I



Map of Experimental Area

Each Block 10 Chains Square

Plot Centers as Marked

APPENDIX II (1)

1952

ROCKY MT. HOUSE

Day	March		April		May		June		July		Aug.		Sept.		Oct.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	7	1	45	22	58	38	63	45	70	41	72	56	70	31	60	40
2	14	-19	44	21	55	25	66	43	71	45	64	50	72	43	75	39
3	10	-3	40	27	55	25	78	39	75	45	71	46	49	46	49	36
4	30	-6	49	22	55	34	77	43	69	47	69	53	55	37	43	24
5	28	-3	67	33	53	29	71	42	54	43	73	45	63	35	52	26
6	36	0	67	38	55	24	60	45	66	38	82	49	75	35	74	21
7	42	14	35	21	63	27	56	33	78	41	58	52	63	44	75	34
8	41	24	34	18	67	28	68	33	85	47	73	46	60	32	74	40
9	29	16	42	13	70	32	66	39	75	52	69	54	49	39	63	37
10	21	12	51	23	72	33	57	41	68	50	62	47	59	36	67	30
11	18	1	44	35	73	40	60	47	62	42	73	38	66	31	65	34
12	22	3	56	29	67	38	48	44	66	45	74	47	51	39	54	39
13	19	2	61	28	68	35	59	38	72	39	83	52	60	37	45	35
14	40	-6	65	32	65	43	66	36	80	48	56	43	72	40	49	25
15	34	-4	59	35	68	43	59	40	70	43	60	46	76	36	54	30
16	46	1	70	30	65	39	60	36	62	50	66	40	61	35	54	35
17	33	9	76	45	72	42	54	35	60	49	71	41	62	39	70	30
18	25	7	66	38	71	47	63	32	63	43	76	42	60	40	66	28
19	28	12	66	41	71	41	70	43	66	50	64	49	65	44	71	28
20	26	2	51	27	61	47	70	45	61	43	72	41	65	38	72	34
21	34	3	67	23	64	44	66	43	51	41	76	42	67	36	64	31
22	44	9	54	32	64	38	62	49	67	47	73	42	73	38	63	29
23	43	31	59	30	61	36	54	47	73	44	73	44	80	36	60	27
24	40	28	71	35	67	30	63	46	69	47	71	43	76	39	47	28
25	40	28	79	41	56	41	68	45	74	50	70	44	86	46	56	33
26	56	28	69	39	60	40	69	44	76	48	65	35	83	52	47	25
27	53	34	68	32	62	29	67	46	65	50	68	38	66	46	49	23
28	58	37	51	35	74	37	61	49	72	45	72	38	69	39	52	29
29	45	23	57	29	50	38	69	49	78	50	39	32	72	47	50	30
30	38	21	67	38	57	37	68	49	80	52	59	32	62	42	60	31
31	41	22			63	38			74	51	53	42			50	28

	March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
TOTAL -	10371	3208	17256	9121	19519	11209	19140	12638
MEAN -	33.5	10.3	57.5	30.4	63.1	36.2	63.8	42.1

	July		Aug.		Sept.		Oct.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
TOTAL -	21472	14219	21030	13657	19834	11753	18240	9615
MEAN -	69.3	45.8	67.8	44.1	66.1	39.2	58.8	31.0

APPENDIX II (2)

1953

ROCKY MT. HOUSE

Day	March		April		May		June		July		Aug.		Sept.		Oct.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	29	10	42	20	35	31	54	42	70	47	57	44	55	45	56	39
2	32	10	46	20	52	32	52	48	70	47	65	40	57	42	55	28
3	32	19	50	19	64	29	53	45	53	45	68	46	61	41	58	35
4	28	20	57	27	71	35	58	45	61	37	74	45	68	37	64	30
5	19	5	49	33	69	45	62	41	68	40	75	46	72	47	67	32
6	40	4	41	26	79	41	67	38	71	45	79	46	80	42	71	34
7	51	24	42	21	81	38	66	43	74	44	84	51	74	43	61	35
8	57	30	32	26	44	37	64	47	79	50	71	55	68	45	72	39
9	60	34	32	24	62	34	65	48	76	53	62	51	73	44	62	33
10	25	9	32	21	55	29	72	43	79	53	73	48	69	38	74	43
11	16	-1	22	16	56	33	77	43	79	53	78	48	73	39	63	45
12	30	12	26	0	57	30	79	46	82	58	65	47	79	51	66	29
13	30	7	22	9	62	31	61	54	80	56	69	46	74	41	59	41
14	35	13	30	6	62	31	69	42	66	56	75	45	68	39	71	30
15	30	12	24	13	62	36	63	39	71	46	80	44	67	35	71	36
16	45	13	35	16	55	40	69	45	70	45	76	50	54	45	72	34
17	38	18	37	7	67	29	58	41	77	44	79	51	60	36	68	36
18	38	14	40	17	75	35	60	37	66	51	81	46	60	38	62	36
19	41	16	61	20	45	40	61	40	62	48	83	47	54	40	57	35
20	35	15	65	30	49	35	53	43	64	45	74	52	57	31	49	36
21	33	17	49	31	46	36	60	42	72	47	66	47	64	29	53	28
22	36	13	57	27	56	38	64	38	75	46	69	42	56	40	63	28
23	41	15	51	29	56	36	56	38	60	41	70	46	45	40	67	27
24	43	22	52	28	55	30	59	41	65	38	70	48	60	35	43	33
25	41	29	53	27	60	39	68	39	60	44	48	46	51	36	41	25
26	53	21	54	34	61	35	65	43	61	43	52	45	60	29	60	32
27	55	23	43	36	62	44	67	42	69	46	59	39	53	32	70	40
28	45	27	42	26	73	39	68	48	70	41	65	37	56	32	70	40
29	48	22	47	31	73	45	61	49	72	45	69	38	51	36	38	31
30	56	27	37	31	54	47	69	42	74	51	67	51	58	31	40	21
31	39	27			48	45			61	48	61	48			52	30

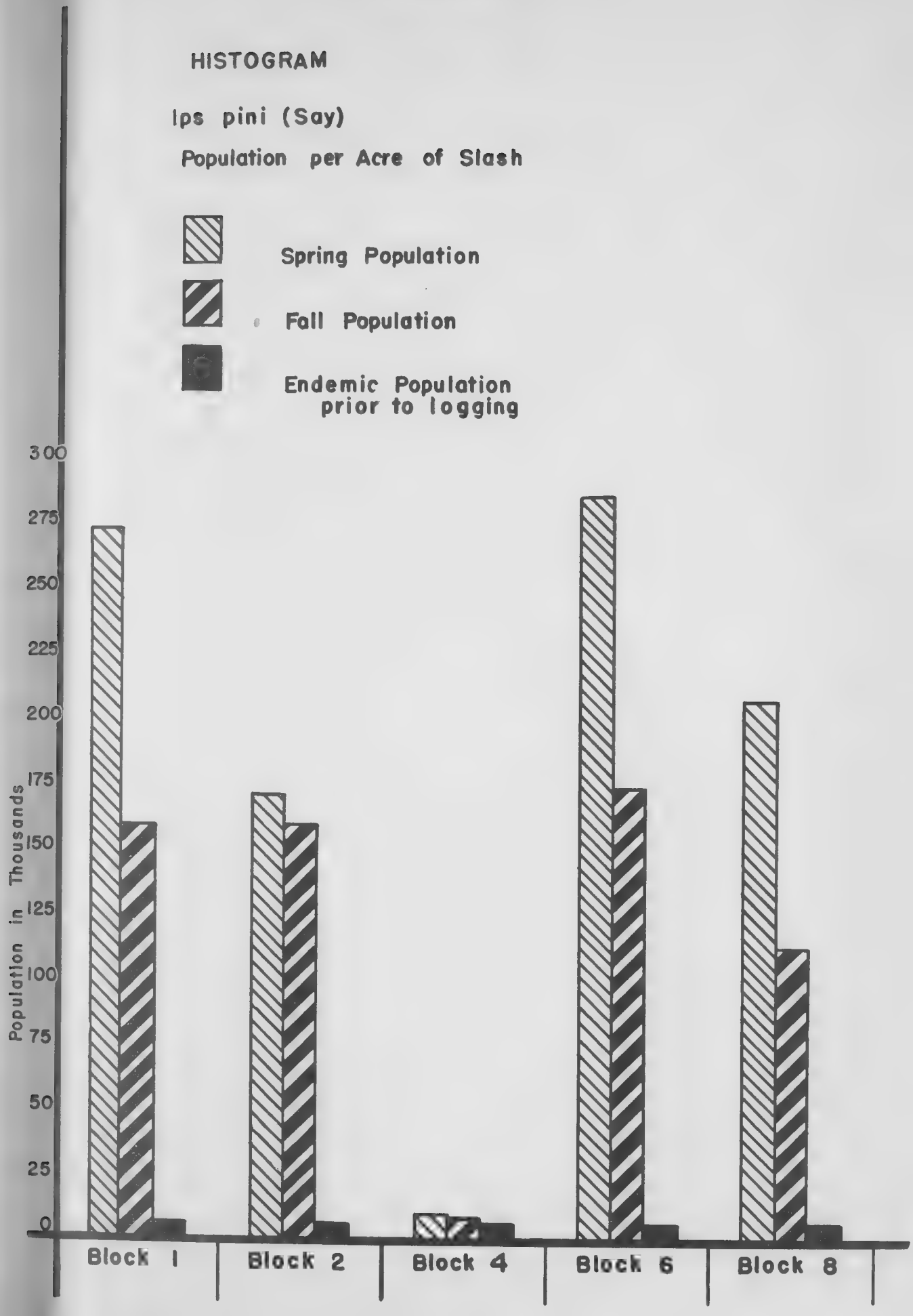
	March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
TOTAL -	11965	526.6	12654	6705	18411	11234	18948	12895
MEAN -	38.6	17.0	42.2	22.4	59.4	36.2	63.2	43.0

	July		Aug.		Sept.		Oct.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
TOTAL -	21528	14537	21608	14339	18730	11570	18689	10378
MEAN -	69.4	46.9	69.7	46.2	62.4	38.6	60.3	33.5

HISTOGRAM

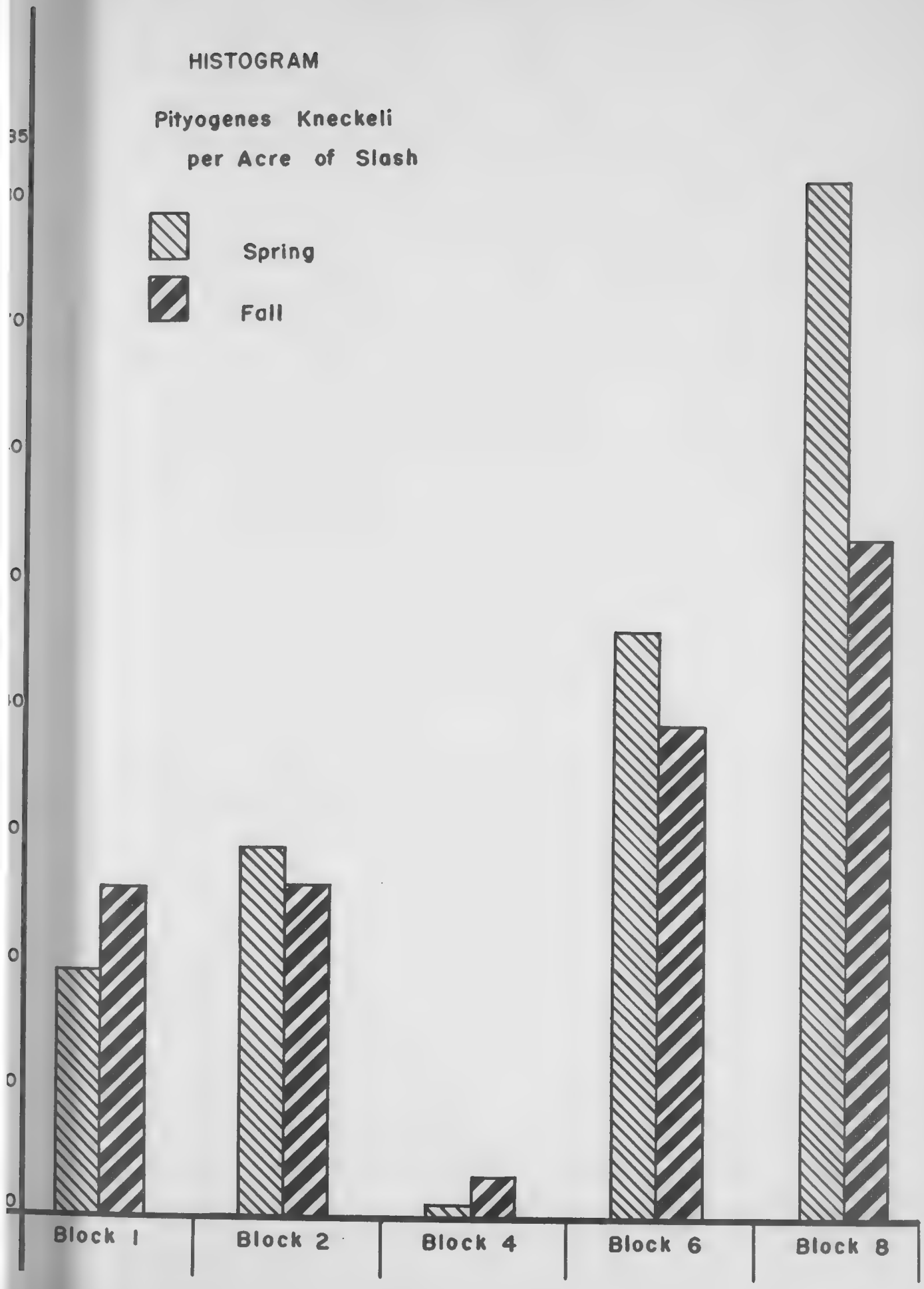
Ips pini (Say)

Population per Acre of Slash



HISTOGRAM

Pityogenes Kneckeli
per Acre of Slash

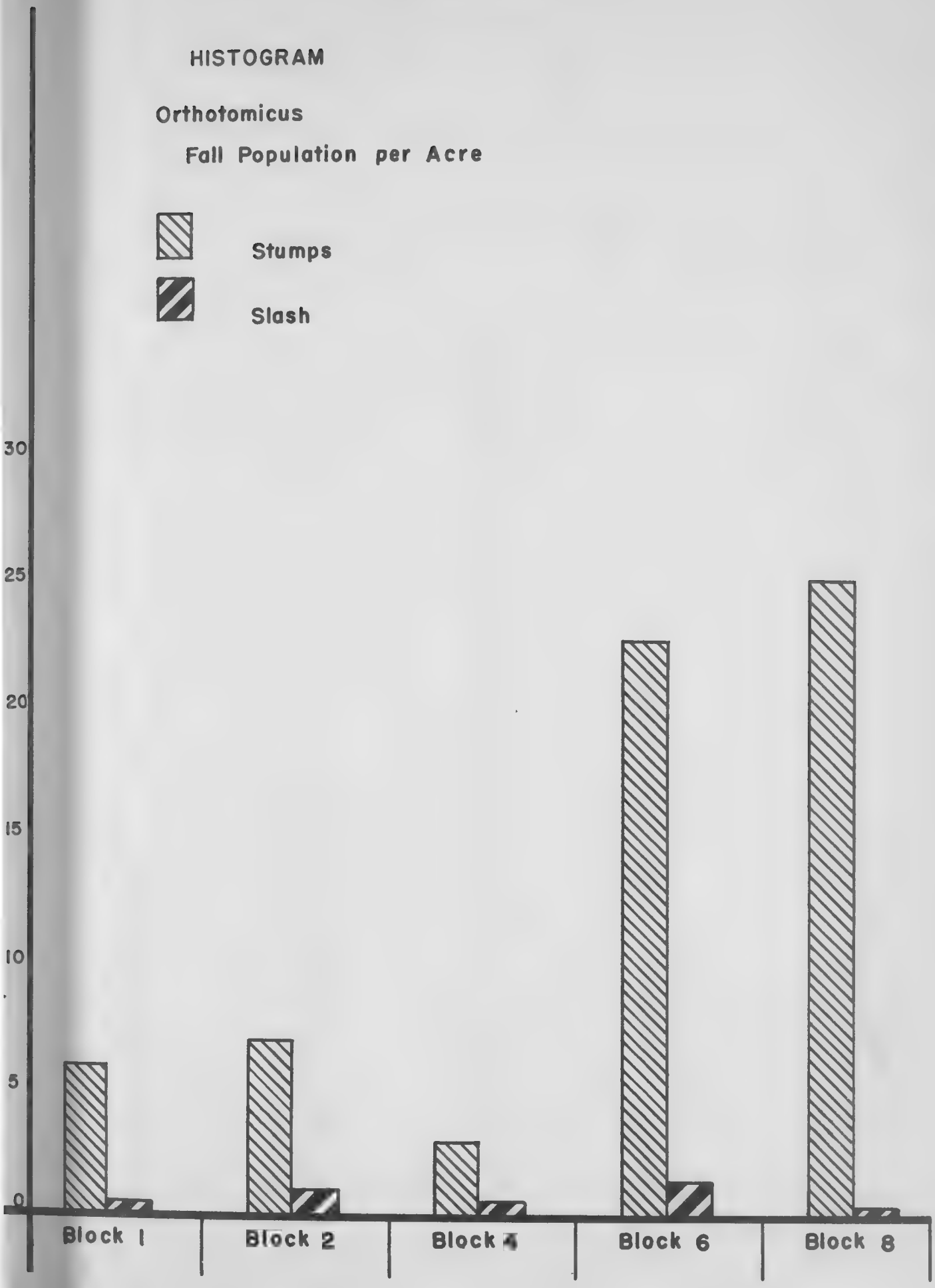


APPENDIX 5

HISTOGRAM

Orthotomicus

Fall Population per Acre



APPENDIX 6

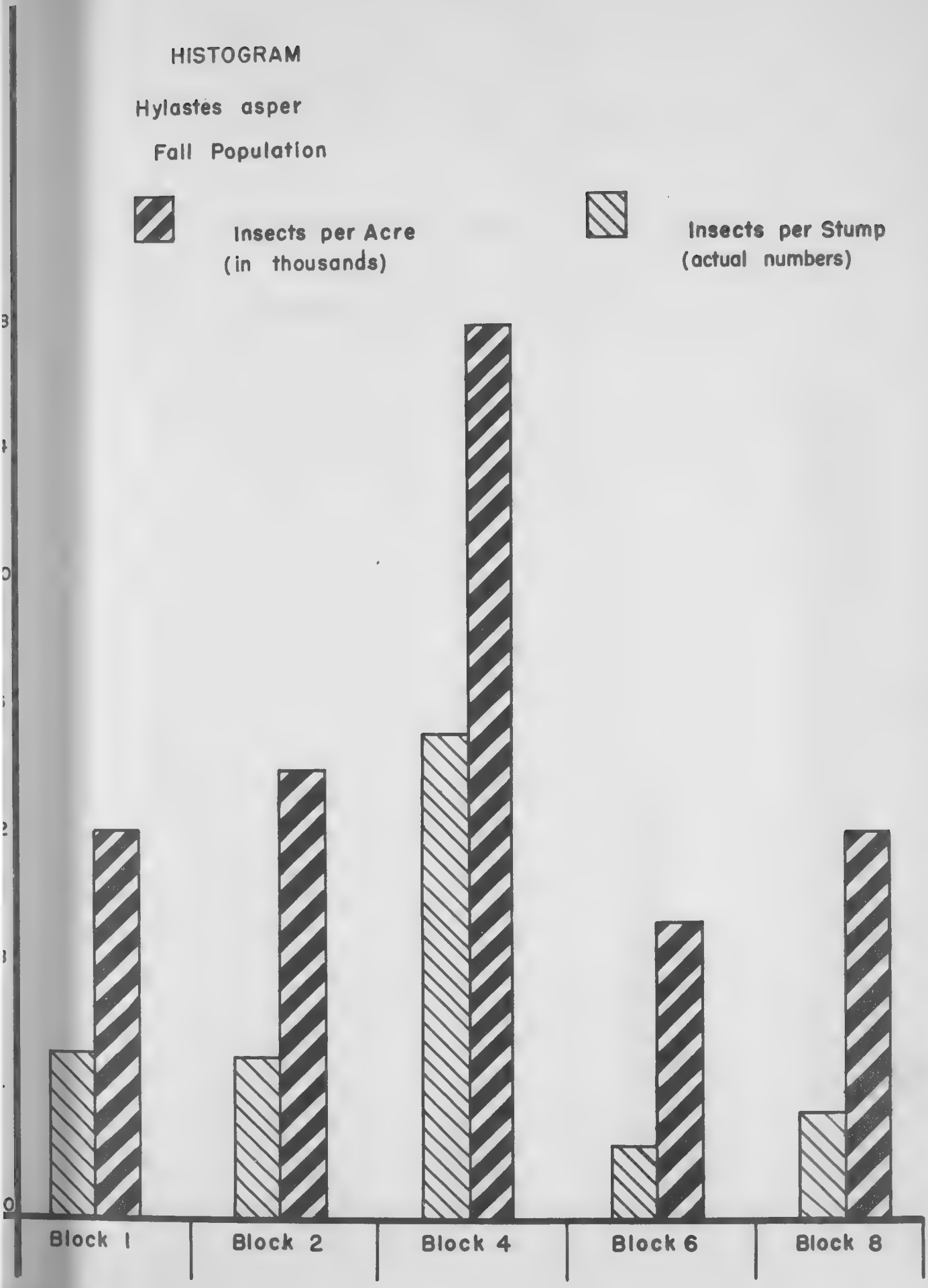
HISTOGRAM

Hylastes asper

Fall Population

Insects per Acre
(in thousands)

Insects per Stump
(actual numbers)

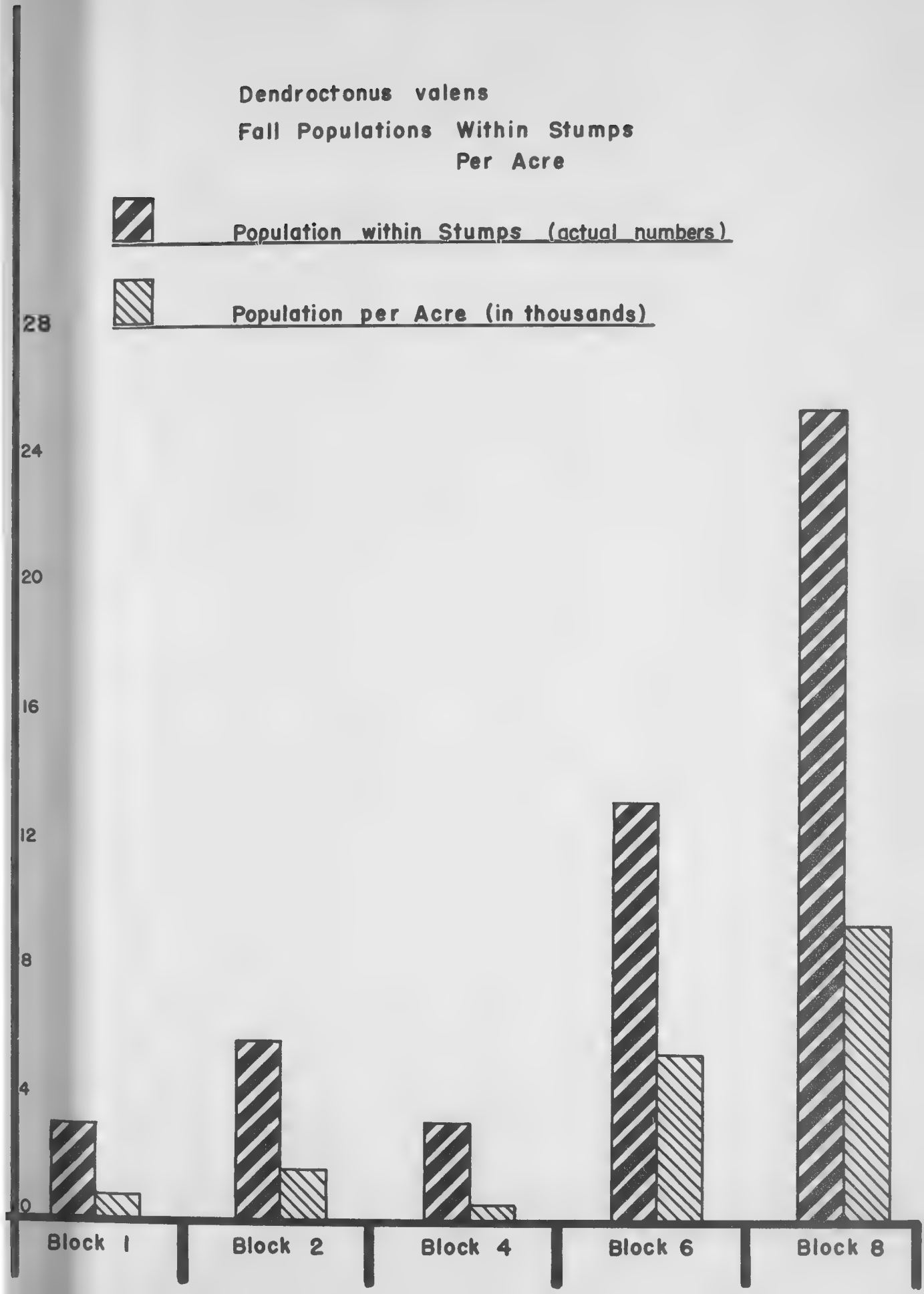


APPENDIX 7

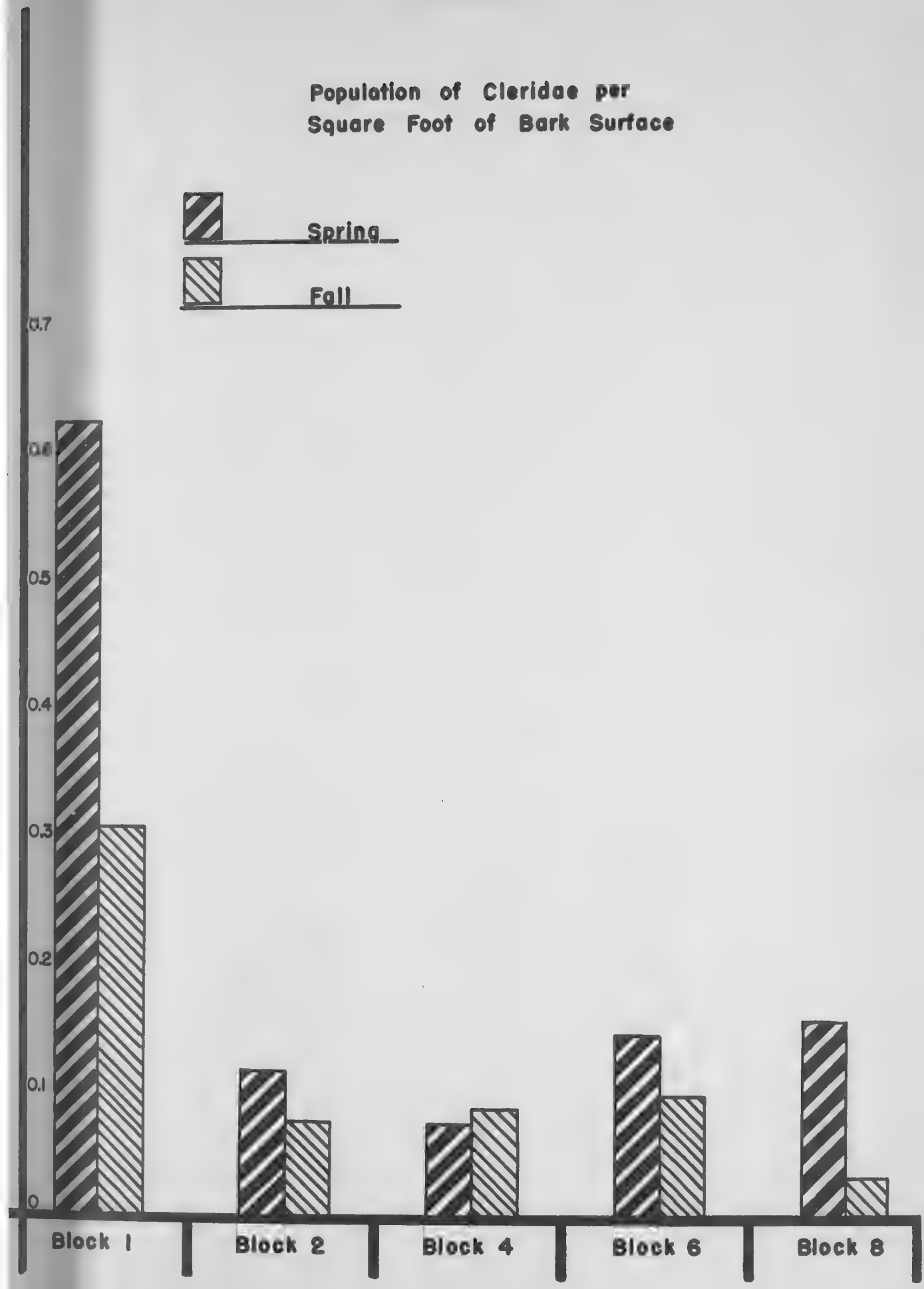
Dendroctonus valens

Fall Populations Within Stumps

Per Acre

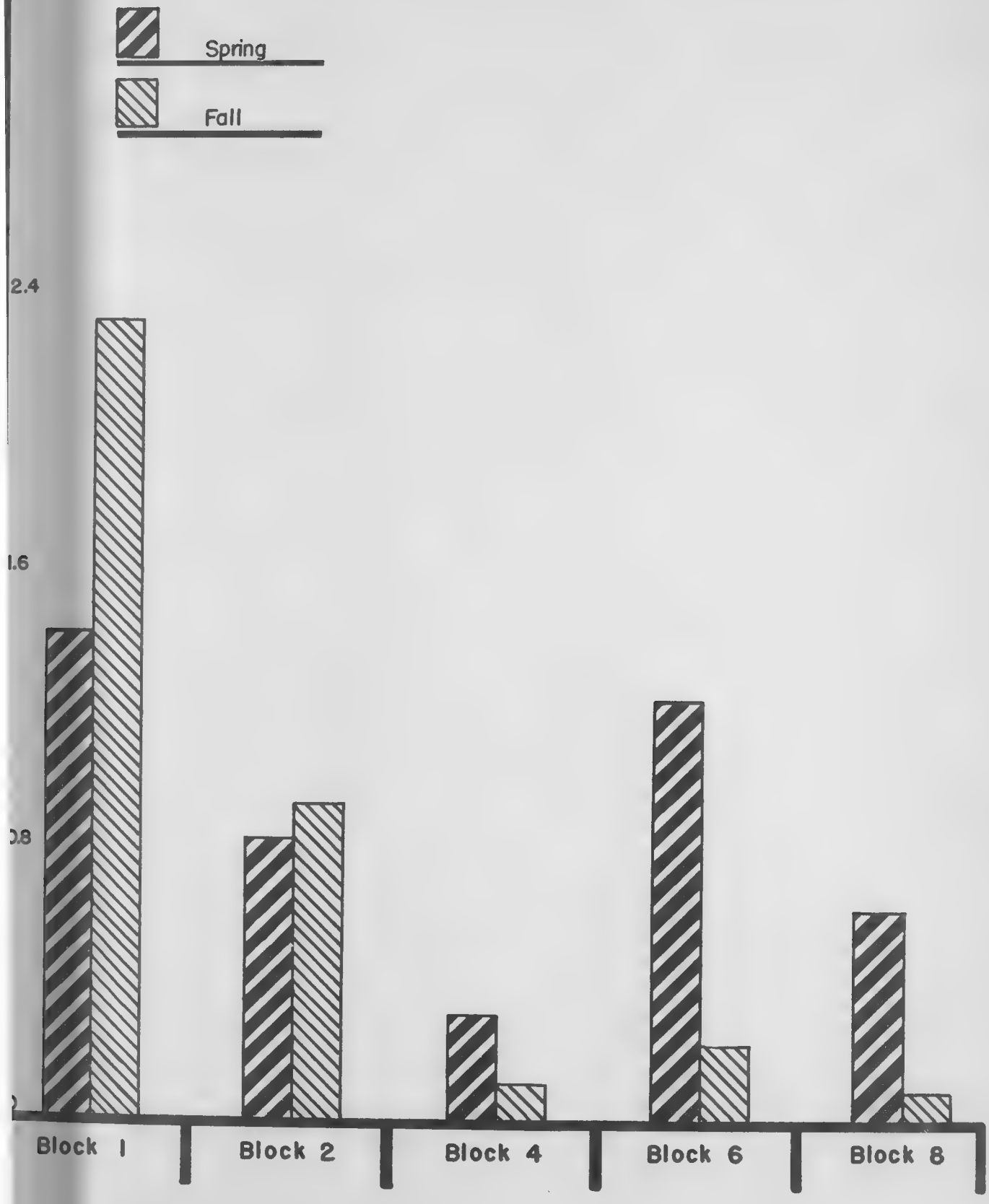


APPENDIX 8

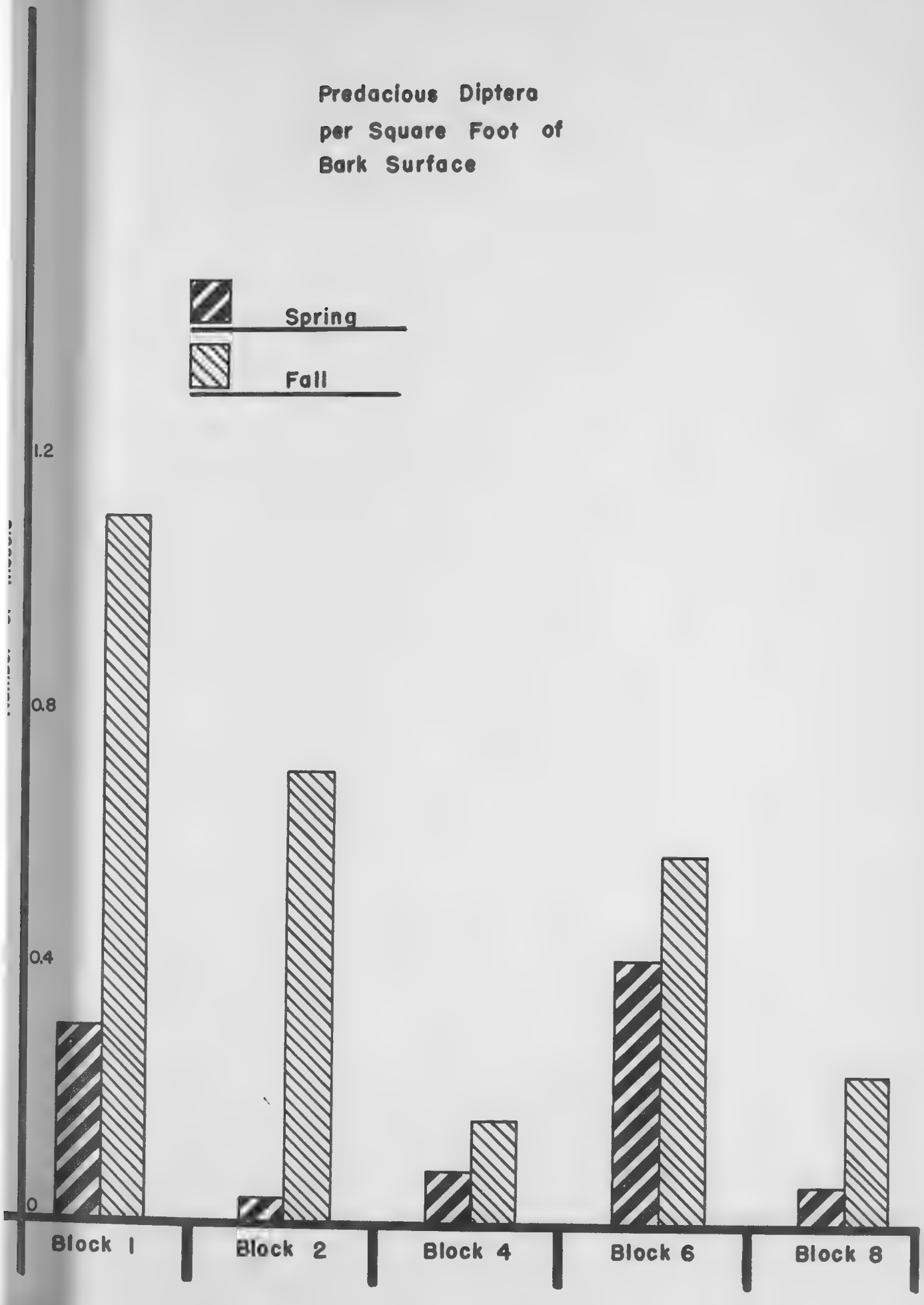

Population of Cleridae per
Square Foot of Bark Surface
Spring
Fall
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Block 1
Block 2
Block 4
Block 6
Block 8

APPENDIX 9

Parasitic Hymenoptera per Square Foot of Bark Surface



APPENDIX 10


Predacious Diptera
per Square Foot of
Bark Surface
Spring
Fall
1.2
0.8
0.4
0
Block 1
Block 2
Block 4
Block 6
Block 8

ANNUAL REPORT - 1953

PART II

BIOLOGIES OF SCOLYTIDAE

TABLE OF CONTENTS

	Page
Introduction	1
Ips pini Say., *Ips* sp.	1
Ips guildi Blackm.	4
Pityogenes knechteli Sw.	4
Orthotomicus sp.	5
Polygraphus rufipennis (Kby)	6
Hylastes asper Sw.	6
Dendroctonus valens Lec.	9

ANNUAL REPORT - 1953

PART II

BIOLOGIES OF SCOLYTIDAE

INTRODUCTION

During the course of the investigation outlined in Part I, some material was collected on the biologies of the Scolytidae associated with lodgepole pine in the experimental area.

Life cycles were studied with cage work supplementing field observations. Egg hatching periods were obtained by collecting newly laid eggs in the field and transferring them to petri dishes in a laboratory tent. The emerging larvae were placed in alcohol to be used for head capsule measurements. Larvae were collected in the field, at intervals and preserved for later head capsule measurements.

IPS

Field observations in 1952, appeared to indicate the presence of two closely related species of Ips. A large species appearing very early in the season, was common in the large pieces of slash. The smaller species appeared later, and for the most part was associated with smaller slash. Size of the adult alone was not a sufficiently good criterion to separate the two types. In most instances however, each form had a distinct gallery pattern. During the 1952 general slash sampling, the two forms were not separated and are referred to in Part I of this report as *Ips pini* Say.

During the 1953 field season, a more critical study was made on the biologies. The 1953 work lent support to the impression that two

a strong possibility that this impression may have arisen from confusion with the second brood, established by the original overwintering young adults. It seems probable that an unusually early spring followed by a warm summer could cause spring broods to mature and establish second broods in August of the same year.

Both forms have been recovered from duff samples. The entry into the duff, and emergence, appears to be related to spring and fall temperatures. The results from spring, summer, and fall duff samples are shown in Figure 1. Date of emergence will vary with exposure of the duff to direct solar radiation.

Entry of Ips into the duff was described in Part I, dealing with distribution of overwintering Ips. In brief, available evidence indicates the young adults drop directly into the duff from the slash above. Figure I shows in graph form, recovery from duff samples taken during spring, summer, and fall of 1953.

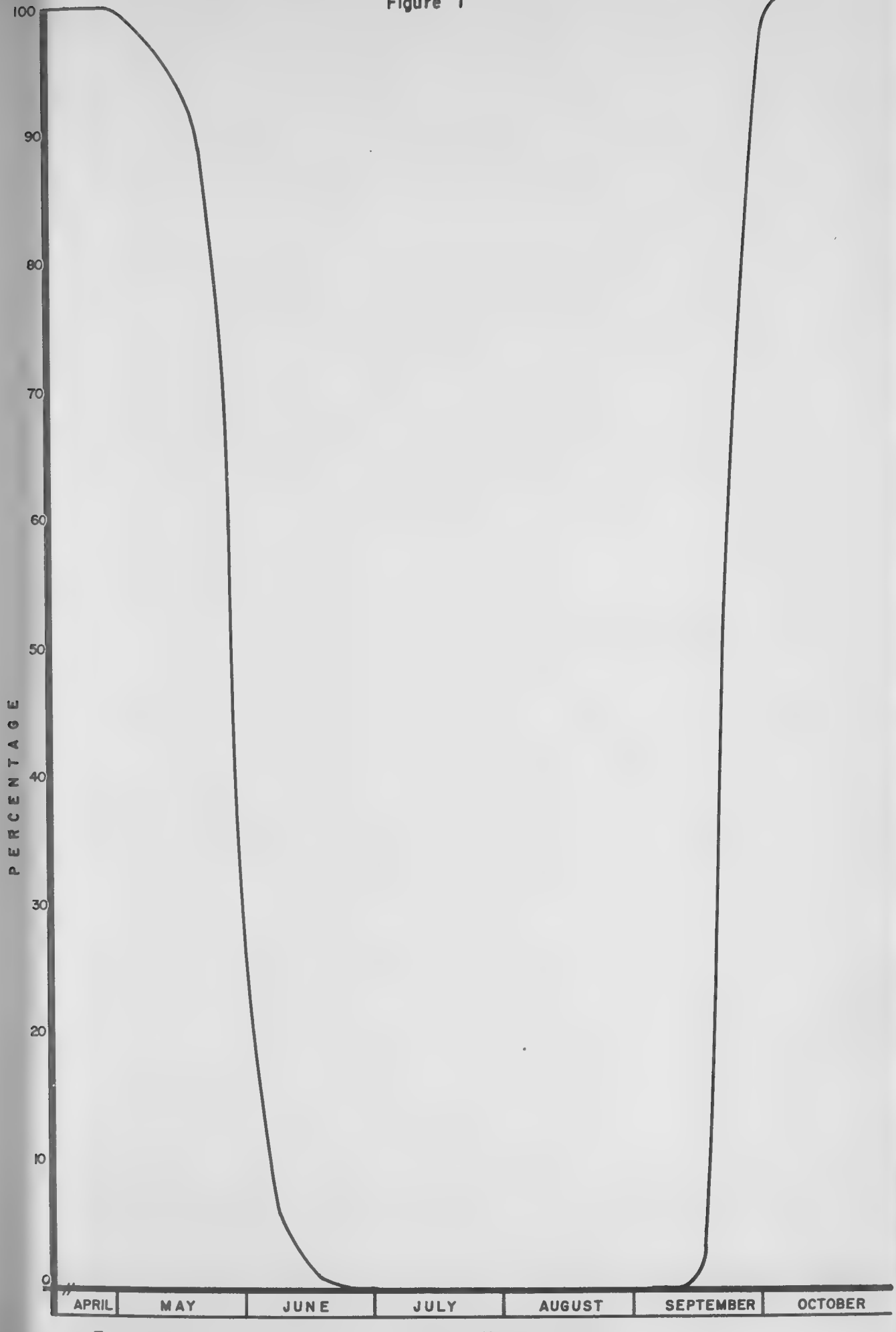
The gallery patterns of the two forms are distinct. Ips pini larvae remain very close to the egg gallery, enlarging an area which is used for pupation. Plate I, Figure 3 illustrates the pattern of pupal chambers within galleries containing mature larvae and pupae.

The larger species of Ips constructs a gallery more like that which is reported for Ips pini. Larvae work out from the egg gallery and establish pupal chambers some distance from the egg nitche as illustrated in Plate II, Figure 3. The majority of galleries in the sampled slash followed this pattern.

Only rarely were combinations of these two gallery types found.

Within standing trees, stem analysis results indicate a higher concentration of Ips in the lower half of the bole.

Figure 1



Emergence and Entry of Ips spp. into Duff —— 1953

IPS GUILDI Blackm.

This species, closely related to I. latiden, Lec. was found commonly in standing trees but no evidence of its occurrence in slash was observed.

This species appears to favour large diameter material. Within standing trees it was found only to a height of 8 feet in the 3 trees analyzed.

Adults were recovered from duff samples taken at the base of the infested trees. Some overwintering larvae were collected from galleries. Little information is available on the life history.

PITOGENES KNECKTELI Sw.

The life cycles, larval head capsule measurements, and gallery pattern are illustrated in Plate III, Figures 1, 2, and 3.

Head capsule measurements indicate 4 instars. However, more measurements are required before this can be established for certain.

The gallery pattern is shown in Plate III, Figure 3. The average number of egg tunnels per nuptial chamber varies from 4 to 6. The tunnels are constructed within the soft inner bark, and the sapwood is engraved very slightly. The larval mines are also confined mainly to the inner bark except when the larvae near maturity. Then small pits in the sapwood are constructed by many larvae, and they pupate within these. Other larvae pupate in shallow excavations constructed in the sapwood. Still others construct pupal cells completely within the inner bark.

Pityogenes knechteli shows a decided preference for small diameter slash. It was seldom found under the bark of stumps. Within 3 standing trees containing this species, it did not occur below a height on

the stem of 15 to 16 feet. The highest number were found above the base of the crown.

Thirteen freshly laid eggs subjected to normal air temperatures hatched in from 9 to 13 days.

Egg counts in 19 galleries averaged 59 eggs per gallery. The number of eggs per strike varied from an average of 27 for 3 egg galleries to 99 for 5 egg galleries.

ORTHOTOMICUS SP.

This species has a life cycle and gallery pattern very similar to Pityogenes knechteli.

Head capsule measurements, starting with recently hatched larvae indicate only three larval instars. (Plate IV, Figure 3.) Here again, as with Pityogenes, more measurements are required.

Adult galleries and larval mines are scored in the sapwood slightly more than occurs with Pityogenes, and the radial character of the galleries is not so pronounced. Pupation takes place within chambers constructed within the bark, or within pits excavated in the sapwood.

Orthotomicus tend to make deeper pits in the sapwood than P. knechteli with an entry hole proceeding directly in whereas Pityogenes tends to slope its entrance hole. The circular holes are plugged with fibrous boring dust, and the pupal cell is an elongated chamber, running parallel with the grain of the wood. These are as deep as 1/8 inch below the surface of the sapwood.

Orthotomicus was confined almost exclusively to stumps, rather than slash. The stem analyses of 3 trees containing Orthotomicus revealed the bulk of the populations occurred in the lower half of the tree.

The hatching period of 7 freshly laid eggs subjected to normal air temperatures varied from 7 to 12 days.

POLYGRAPHUS RUFIPENNIS (Kby)

This species did not occur in significant numbers within the experimental area.

Its life cycle and gallery pattern are illustrated in Plate IV, Figures 1 and 2.

It overwinters mainly in the larval stage. The flight periods of Polygraphus occur later in the season than the bark-beetles discussed previously.

This insect appears to attack in either pairs or in threes. One or at the most two egg galleries are constructed from the nuptial chamber as illustrated. Nuptial chambers and adult galleries are deeply engraved into the sapwood.

Eggs are laid 2 or 3 deep, along the sides of the egg galleries. They are packed in securely with boring dust. The larvae work away from the egg gallery, mining individual tunnels. Pupation occurs in shallow depressions which lightly engrave the sapwood at the end of the larval gallery.

HYLASTES ASPER Sw.

This species was very abundant in the experimental area, and was confined entirely to stumps.

The 2 year life cycle is illustrated diagramatically in Plate V, together with the results from larval head capsule measurements. Hylastes attack the base of stumps in pairs, just above or below the upper level of the duff. The adult galleries run several inches above

and below the entry hole. Eggs are deposited within shallow depressions along the sides of the galleries, from 1 to 5 in depth and packed in with boring dust. The gallery pattern and larval habits are very similar to those described in the literature for Dendroctonus valens.

In their early stages the entire brood works away from the egg gallery into the roots in one large group. Later it becomes separated into smaller groups, and by the time the larvae have reached maturity, they can be found singly or in groups of 2 to 6. Larvae have been found, along the large lateral roots several feet from the egg gallery. Larvae also work down the tap root well into mineral soil. If competition is not too severe some larvae remain working in subcortical regions above the level of the duff.

The greatest percentage overwinter as larvae, pupating in the late summer of the following year.

Head capsule measurements indicate the presence of 4 larval instars, (Plate V, Figure 2.) The first, second, and third instars and a few of the fourth were collected during the 1952 season. They appear to spend most of the following summer as IV instar larvae and pupae. Young adults overwinter within the larval galleries, or emerge and overwinter in the duff.

There are considerable differences in the temperatures of the subcortical regions where the larvae work. This is reflected in the varying rate of development of the larvae. While the life cycle described in Plate V holds for the main population, portions of a single brood may differ considerably in rate of development.

Bark temperatures below the duff level were recorded for two

separate exposed trees on different days at 3:00 P.M. in the afternoon. The results are given in Table XXXVI. Temperatures are in centigrade degrees.

TABLE XXXVI - Root Surface Temperatures at Various Levels in Duff(C°)

	Tree #1		Tree #2	
	South Aspect	North Aspect	South Aspect	North Aspect
Air temperature	22.5°C	22.8	24.5	22.5
Bank temperature - upper duff level	39.0°C	21.5	45.5	21.5
Temperature 1" below duff	24.5°C	15.5	26.0	14.5
" 2" " "	17.5	15.0	21.0	14.5
" 4" " " (lower level)	14.0	13.0	17.0	14.0
" 6" " " (mineral soil)	12.3	13.0	13.0	12.5

Within the experimental area, Hylastes adults established a large number of broods within stumps in the spring and early summer of 1952. In September the bulk of the broods were in the larval stage except for a very small percentage which had reached the pupal stage. They remained, for the most part, as larvae during the following summer and some spent the second winter in this stage. During late summer of 1953 most of them had become pupae and some had reached the young adult stage. These young adults commonly emerged but did not establish fresh broods.

The development of these broods appeared to be directly related to the location of the larvae. Table XXXVI illustrates the great differences in temperatures which occur below the duff level. The life cycle of this species seems to very from 1 to 2 or 2½ years, resulting in the flight period of adults throughout a good part of the summer.

This staggering of the life cycle, where adults appear and establish broods throughout the season, seems to be a common feature of many root inhabiting forest insects. It is probably due to the temperature differences discussed above.

DENDROCTONUS VALENS Lec.

This species behaves much like Hylastes asper.

Adults of this species are commonly observed in flight during the entire summer season. This extended flight period has been attributed to the great contrasts in temperature within subcortical regions where these larvae are found, and the resultant differences in the rate of development.

PLATE I

Figure 1 Showing life cycle of Ips pini Say - (1953)

Figure 2 Larval head capsule measurements of Ips pini Say.

Figure 3 Typical gallery of Ips pini Say. Note pupal chambers lying immediately adjacent to secondary galleries.

Figure 1

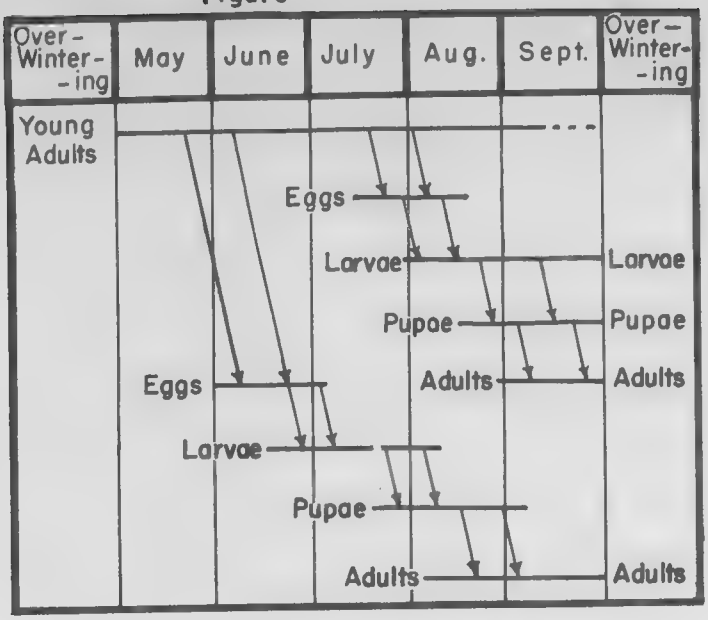


Figure 2

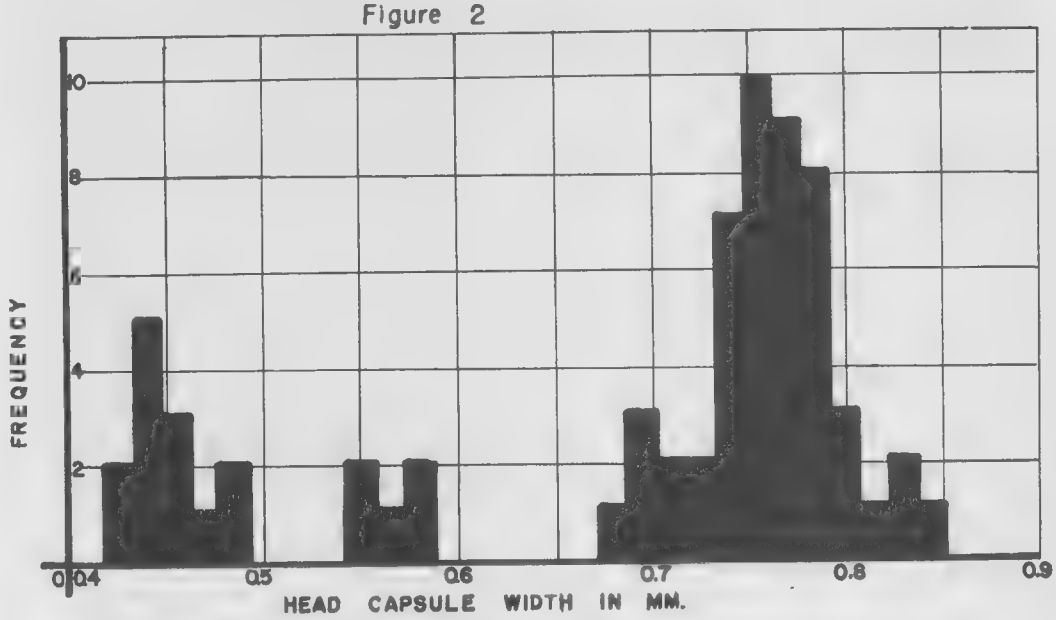


Figure 3

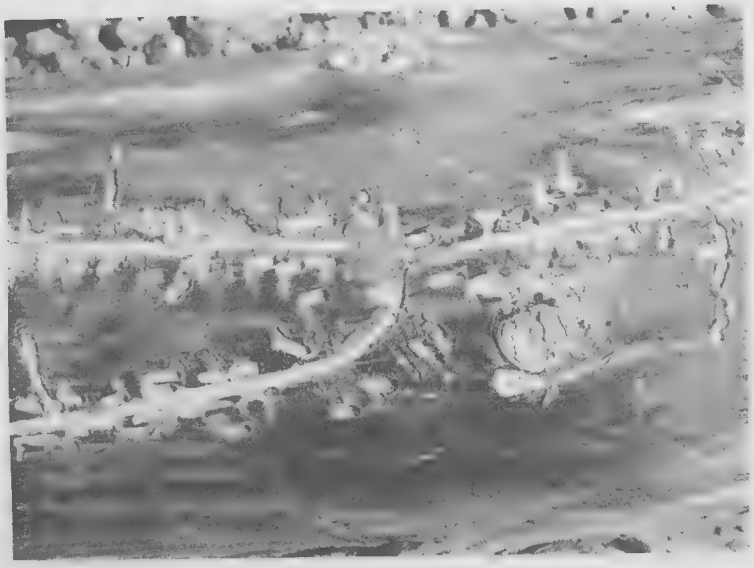


PLATE I

PLATE II

Figure 1 Showing life cycle of Ips sp. (1953)

Figure 2 Larval head capsule measurements of Ips sp.

Figure 3 Typical gallery of Ips sp. Note long winding larval galleries, extending some distance from secondary galleries.

Figure 1

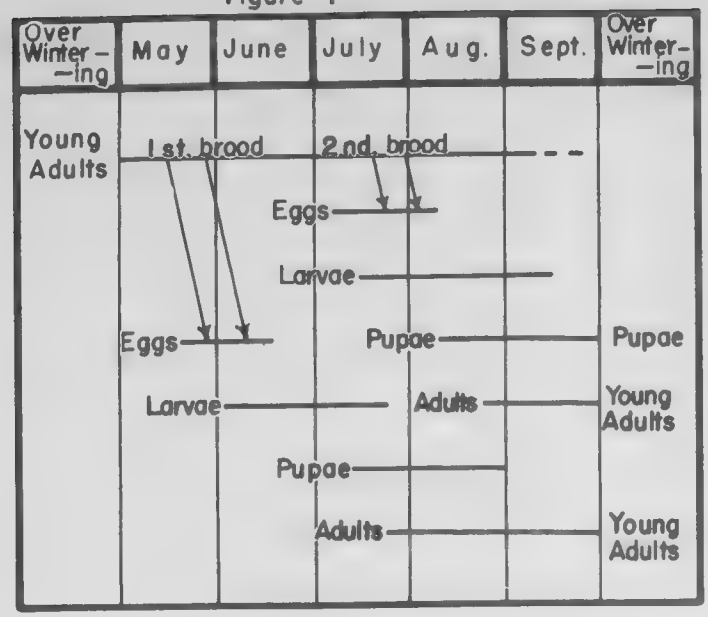


Figure 2

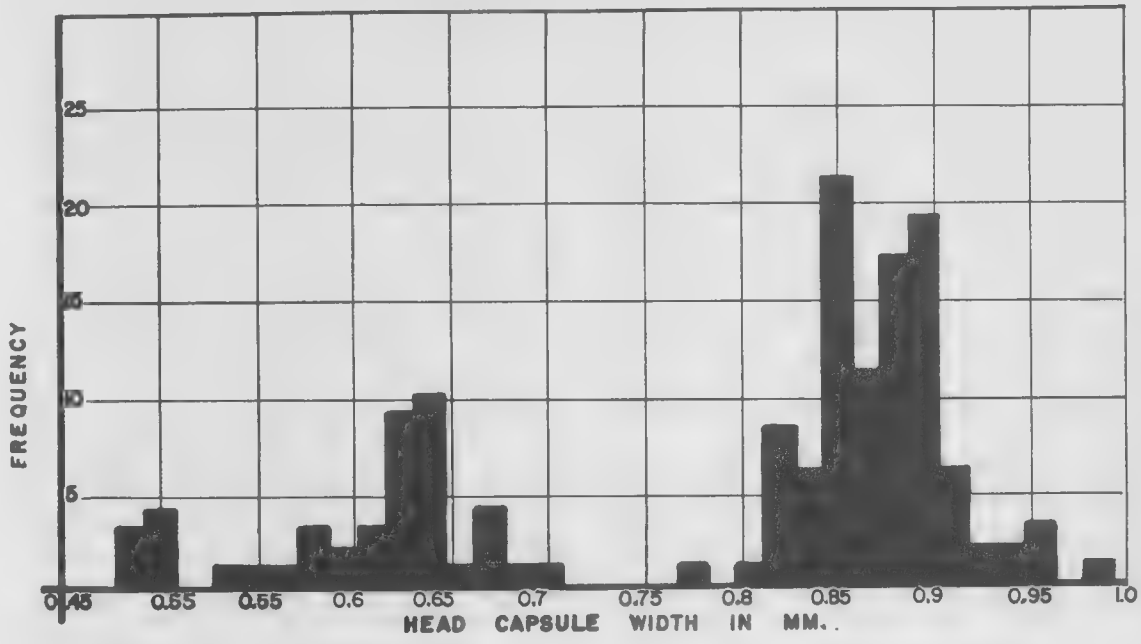


Figure 3

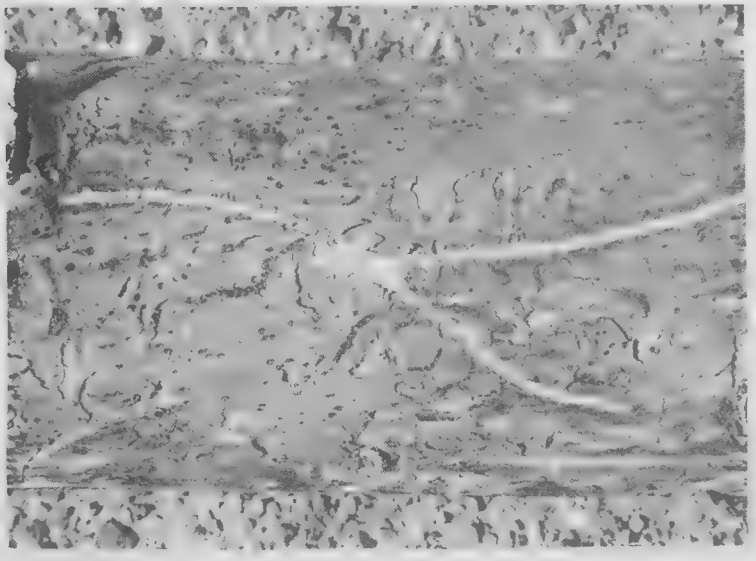


PLATE II

PLATE III

Figure 1 Showing life cycle of Pityogenes knechteli

Figure 2 Larval head capsule measurements of Pityogenes knechteli

Figure 3 Typical radiating gallery of Pityogenes knechteli. This photograph was taken before the eggs had hatched.

Figure 1

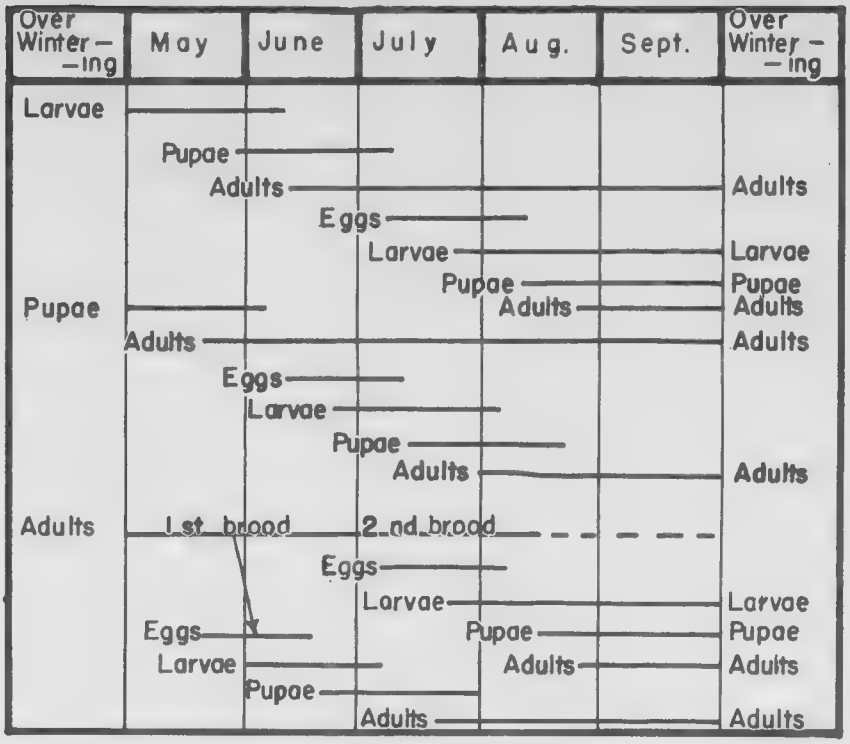


Figure 2

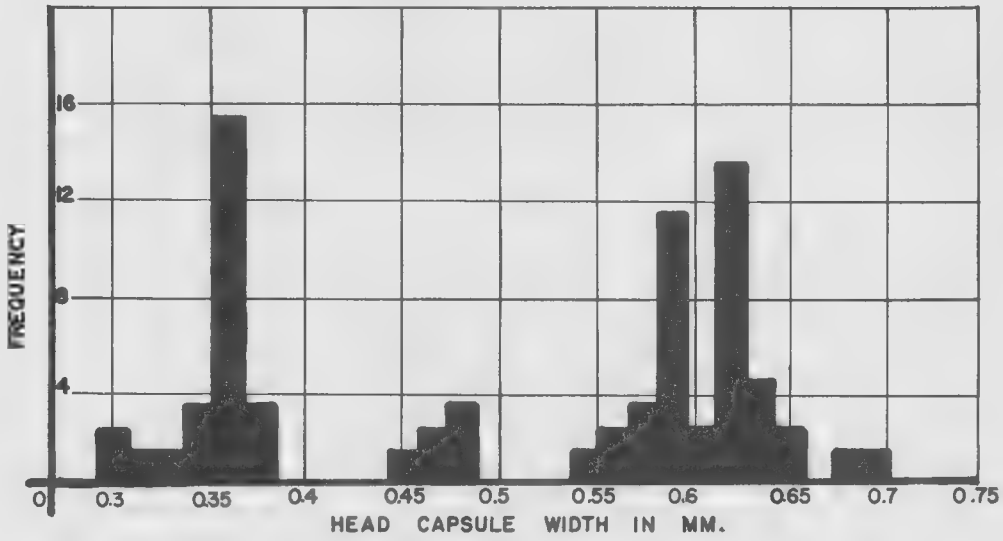


Figure 3

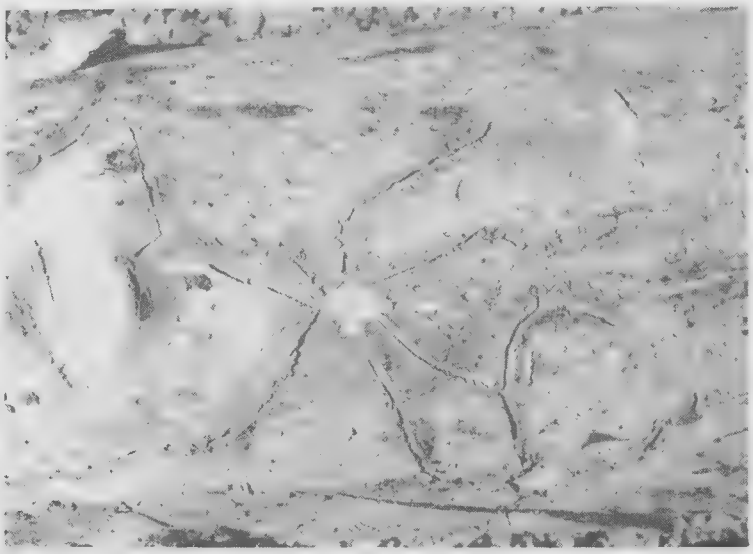


PLATE III

PLATE IV

Figure 1 Showing life cycle of *Polygraphus rufipennis* (1953)

Figure 2 Typical gallery of *Polygraphus rufipennis*

Figure 3 Larval head capsule measurements of *Orthotomicus* sp.

Figure 1

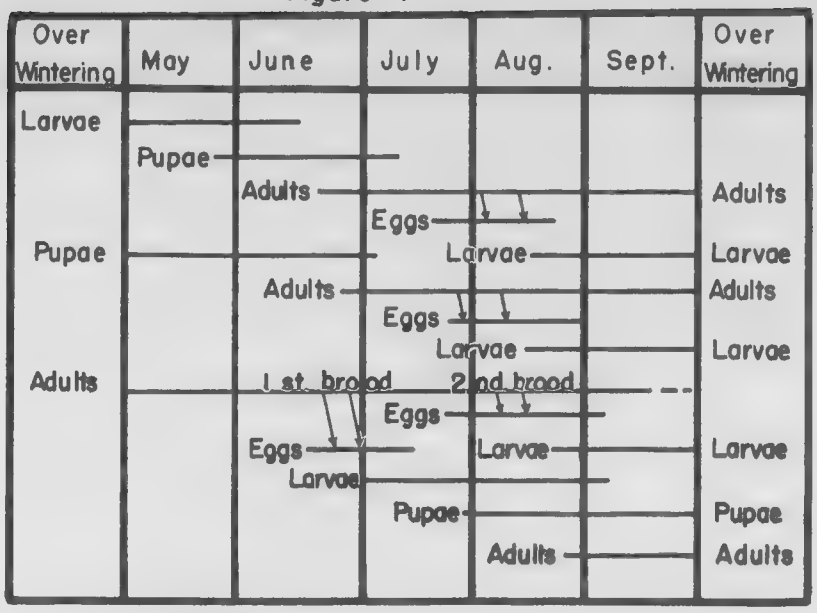


Figure 2

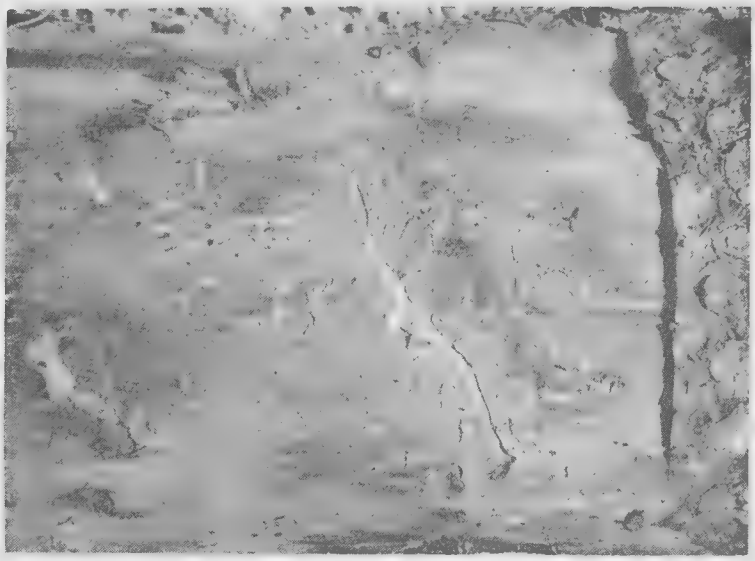


Figure 3

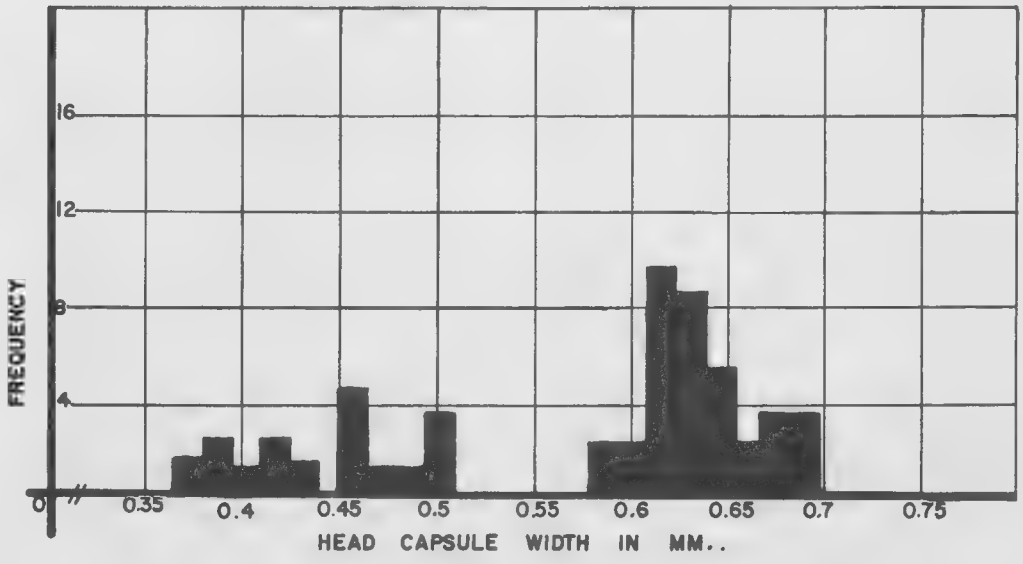


PLATE IV

PLATE V

Figure 1 Showing life cycle of *Hylastes asper* (1952-1953) indicating a 2 year cycle.

Figure 2 Larval head capsule measurements of *Hylastes asper*

Figure 1

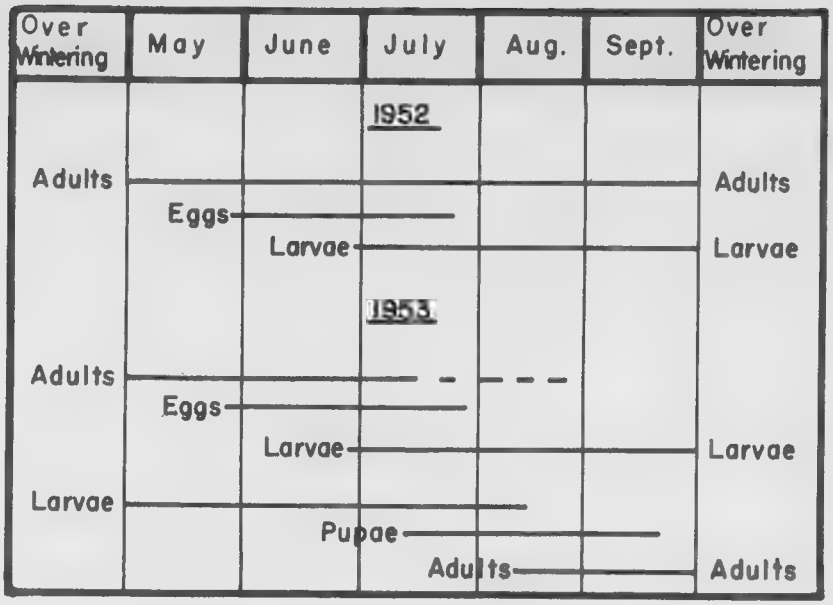


Figure 2

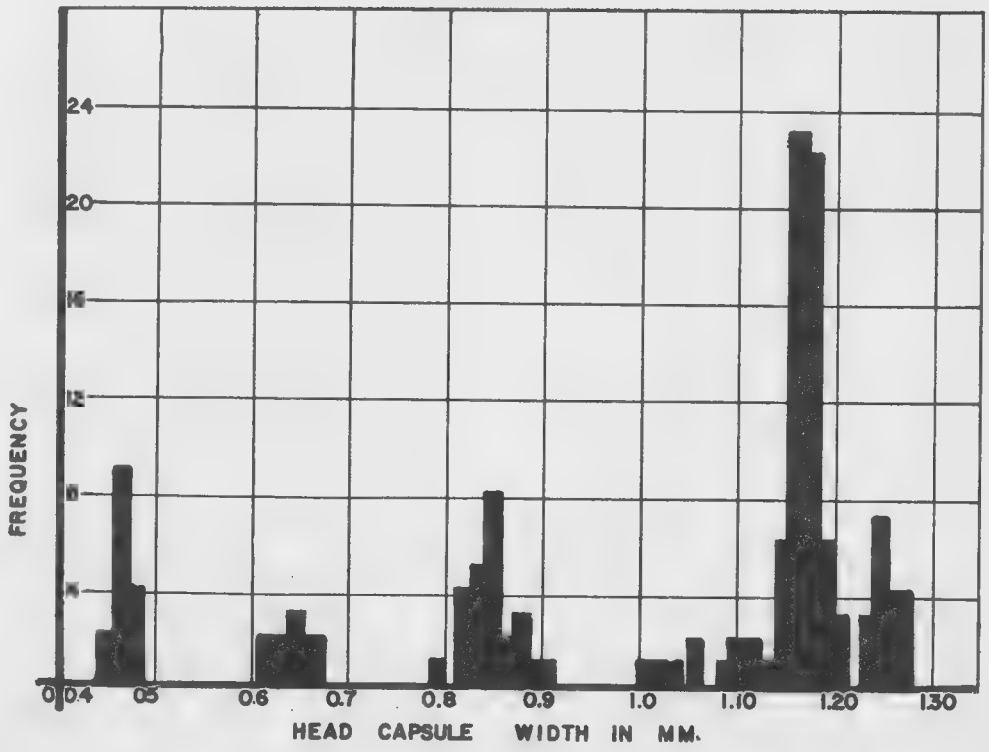


PLATE V

ANNUAL REPORT - 1953

PART III

BIOLOGIES OF PREDATORS AND PARASITES

TABLE OF CONTENTS

	Page
INTRODUCTION	1
HYMENOPTERA	2
DIPTERA	3
COLEOPTERA	5
HEMIPTERA	11
ACARINA	11

ANNUAL REPORT - 1953

PART III

BIOLOGIES OF PREDATORS AND PARASITES

INTRODUCTION

Ips pini Say. and Ips sp. are the most important hosts of predators and parasites discussed in this part. Observations on other hosts are also given.

Information on the biologies was obtained from field observations supplemented by laboratory rearings of immature forms. Predacious and parasitic larvae, together with food in the form of Ips larvae and pupae, were placed in petri dishes between disks of bleached blotting paper. Depending on the food habits of the particular species, fresh host material was placed between the disks as required.

Members of the following orders were found associated with lodgepole pine bark beetles.

Hymenoptera	-	3 species of Braconidae
		3 species of Pteromalidae
Diptera	-	1 species of Coenomyiidae
		1 species of Chloropidae
		1 species of Lonchaeidae
		1 species of Dolichopidae
Coleoptera	-	2 species of Cleridae
		1 species of Histeridae
		1 species of Ostomidae
Hemiptera	-	1 species of Anthocorrinae
Acarina	-	1 species of mite

HYMENOPTERA

Braconidae

Two genera were represented from this family; Coeloides sp. and 2 distinct Spathius sp. These were identified by J. M. Mason of the Systematics Unit.

All three species appear to have similar oviposition, larvae and pupating habits. The oviposition period extends over three to four weeks following the initial attack on slash by a flight of bark-beetles. Females move rapidly over a small area of bark, constantly tapping with their antennae upon the bark surface. When a suitable site is found, oviposition takes place through the bark. It was not determined where the egg is deposited but when the bark was removed from the oviposition site, bark-beetle larvae were either directly under or in the very near vicinity. It would appear unlikely that the parasite lays its eggs within the host. The larvae were observed in various stadia attached externally with their mouth parts imbedded in the host. They are not capable of locomotion by themselves, but appear to have a mucilagenous-like covering and readily adhere to the host on the slightest contact.

Larvae overwinter either naked or within cocoons. The less naked larvae spin cocoons in the spring. The two genera are easily separated by the type of cocoon constructed. Coeloides form white fragile cocoons up to 6 mms. in length, firmly attached to the larvae gallery or pupal chamber of its host. Spathius constructs a much tougher elongated dark tan cocoon. Generally these latter type cocoons are smaller, and not so securely attached to the host gallery. Adults have been reared from both types of cocoons.

Pteromalidae

These did not occur in as high numbers as the braconids but were

still plentiful enough to exert a considerable pressure on the bark-beetle population. Three common species present in the area were identified by Dr. O. Peck of the Systematics Unit as: Pachycerus xylophagorum Ratz., Rhopalicus pulchripennis Cwfd., and Tomicobia tibialis Ashm.

Pachycerus and Rhopalicus behaved very much like the braconids but appeared to move much more rapidly over the bark, and to oviposit with much less care in selecting the site. The larvae were not distinguished from the braconids among the bark-beetle broods. The pupae are naked however, and overwinter mainly in this stage. Adults of these species have been reared from larvae.

Tomicobia was first observed in the pupal stage within fully mature but dead adults of Ips pini and Ips sp. A number have been reared through to adults. During the spring flight of Ips, a small hymenoptera, captured and identified later as T. tibialis, was observed following an Ips adult which was moving over the bark prior to locating its entry hole. This parasite periodically attacked the bark-beetle and with great speed and rapid movement of its ovipositor attempted to deposit eggs either on or within the host.

In the fall, many of the dead adult Ips found in main galleries and appearing to be the parents of the brood, contained Tomicobia pupae occupying the complete abdominal and thoracic cavity. The pupae overwinters in the host, emerging in the spring by cutting a round hole through the elytral declivity or posterior ventral portion of the abdomen. No parasites were recovered from teneral adult Ips.

DIPTERA

Several members of this order were observed attacking bark-beetles

and wood boring larvae. A species of Xylophagus was common in the stumps. It has a sclerotized anterior portion culminating in a sharp lance-like projection, and attains a length of 15 mm. No adults were reared through and little is known of this species other than it has a naked pupa, and was observed feeding on the large cerambycid and buprestid larvae in the stumps.

Four smaller Diptera, associated with Ips, have been identified by J. F. McAlpine of the Systematics Unit. Information is very sketchy on three of these, Oscinella sp. nr. magnipalpus, Beck; Lonchaea corticis Taylor, and species of Chloropid. All three species were captured as adults ovipositing in boring dust, and entry holes of Ips pini galleries. No specimens have been reared through.

The fourth dipteron, and by far the most common, was identified from reared adults and captured specimens as Medeterus modestus, Van Duzee.

Adults were seen ovipositing within newly established Ips galleries, and in the boring dust adjacent to the entry holes. Larvae of this predator were very active, feeding on bark beetle larvae and pupae. In the late summer and early fall, the predator constructs a pupal cell and remains as a larva through the winter. The pupal cells are lined with silk, forming a very fragile cocoon which is closely attached to the surrounding bark fibre. They are found occasionally within larval galleries but most commonly are imbedded within the inner bast layer of the bark, close to bark beetle galleries. The larvae within the cocoon are bent double, "hairpin-like" and remain thus through the winter. Pupation and emergence occurs in the spring with the advent of warm weather.

COLEOPTERA

Five species of beetles, identified by E. C. Becker of the Systematics Unit, were commonly found in Ips galleries, some in larval and adult stages, some only in the larval stage. Only two species were observed actually feeding on the bark beetle broods. Both belonged to the Cleridae family and only the larvae were observed in the galleries. The beetles, other than clerids, found within the host galleries were: Epuraea linearis Maklin; Corticeus sp.; Platysoma coarctatum Lec. These species occurred as both larvae and adults, but on no occasion were they observed feeding on bark beetles or bark-beetle broods.

Two species of Cleridae were associated with bark beetle broods. Enoclerus sphegeus Fab. was by far the most common affording sufficient material for study. The other species was Thanasimus undulatus Say.

Enoclerus sphegeus Fab.

The abundance of this species and the ease with which it could be handled, both in the adult and larval stage, permitted the gathering of considerable information on its development and behavior.

Egg stage - The eggs are 2.6 mm. in length and 0.8 mm. at the widest part, pink in color initially, with white portions appearing on both ends as the embryo reaches maturity. Eggs are laid under bark scales, at the entrance to the bark beetle galleries, and in boring dust at the entry hole. Occasionally some eggs are laid several inches from the nearest entry hole. The survival of young larvae in this latter case is doubtful, for reasons which will be explained in discussing first instar larvae. The eggs are attached by one end to the bark scale, well protected from direct radiation and other predators. Eggs

secured from captured speciments took from 19 to 22 days to hatch. It is very probable that this hatching period would be considerably less, had the eggs been subjected to bark temperatures rather than the air temperatures existing within the laboratory tent where they were being incubated.

First Instar - The first instar larvae are 6 mm. in length, the head capsule width being 0.55 mm. The head and thoracic shield are brown, the remainder of the body being a pale reddish colour.

Reared specimens remained in this stadia from 7 to 14 days, although one larva molted to second instar after 2 days but died soon after. It had not fed at all in the first stadia.

This initial instar is very feeble, and when eggs are deposited any distance from a bark-beetle entry hole, it is improbable that the first instar larva is able to locate and enter before it is destroyed by other predators, excessive bark temperatures, or starvation.

The first instar larvae were able to attack successfully only first or early second instar Ips larvae.

Second instar - The second instar attains a length up to 21 mm., while the head capsule increases but little over the first instar, being 0.60 mm. in width. The head and thoracic shield, the sclerites on the meso-and meta-thorax, and the anal plate are dark brown. The remainder of the body is white to pale pink.

This is the period of greatest predation and larvae remain in this stadia up to 35 days. Predation is confined to bark-beetle larvae and pupae. A single Enoclerus, reared to check the number of instars, consumed 33 Ips larvae and pupae during its second stadia.

When the second instar larvae near maturity they cease to feed,

remaining stationary for periods up to 4 or 5 days. During this time, the first thoracic segment swells considerably, and head and thoracic appendages lose much of their powers of movement.

Third instar - The third instar larva reaches a length of 23 mm. The head capsule is 1.3 mm. in width, more than twice the size of the second instar head capsule. Sclerotized areas are dark brown, and the body becomes pink to reddish. In this stage, larvae are able to destroy teneral Ips adults but feed on mature larvae and pupae in preference.

This instar is common in September when the bark bettle broods are rapidly approaching maturity. The food supply for this, as well as the fourth instar may become critical if the bark-beetles begin to leave the galleries. A specimen in the third instar destroyed between 6 and 10 teneral bark beetles.

The increase in head capsule size between the second and third instar larvae is worthy of note. Many larvae were observed going through this molt. The head capsule splits down the median suture and appears to contain only a portion of the mandibles which appear to be larger than the entire second instar head capsule.

Fourth instar - This is the final instar, which may reach a length of 26 mm., the head capsule width measuring 1.4 mm. At maturity the head is very dark brown, thoracic sclerites and anal plate also dark brown. The body is purple.

During the time of the second Ips brood these predacious larvae are not so numerous as with the first brood. The parents of these clerid larvae may be survivors of the original adult Enoclerus population as well as late emerging overwintering larvae.

With the advent of cool fall days and the disappearance of much of the bark beetle broods, the fourth instar larvae leave the slash and drop into the duff, overwintering there in the larval stage. Most larvae overwinter in the fourth instar without forming cocoons, which are spun in the spring. Fourth instar larvae commenced construction of cocoons 20 days after being brought into room temperature. The prepupal period extended from 10 to 12 days within the cocoon, the pupal period from 15 to 20 days. The fully colored adults remained within the cocoons for periods up to 7 days before emerging.

Mature adults of the host are destroyed within the galleries by fourth instar larvae. Large buprestid and cerambycid larvae in the vicinity of the bark beetle broods are also destroyed by clerid larvae in this stadia. While this is a very active stage in the development, frequently food is at a premium, and the larvae apparently can go for some time without feeding. One larva pupated and emerged successfully after having been fed only 4 teneral Ips in the fall. They do not feed in the spring prior to pupation.

Discussion on larval habits - Enoclerus sphegeus

Some idea of the capacity of a single Enoclerus larva can be gained from the consumption by a single larva reared from egg to fourth instar. Approximately 40 larvae, pupae and adults were consumed. However, this figure cannot be taken as typical because food was supplied in over-abundance, the main purpose being to rear it through. Probably it could have survived on much less.

Observations on the larval feeding habits, in the field and in the laboratory, indicate a decided preference for Ips larvae and pupae, even when hymenopterous and dipterous larvae are common. Several second, third and fourth instar Enoclerus larvae were placed in direct

contact with larvae of Hymenoptera and Diptera. In all cases the Enoclerus larvae, even when partially starved, showed a decided aversion to consuming these smaller forms. The hymenopterous larvae in particular appeared to be distasteful. When annoyed by constant contact with hymenopterous or dipterous larvae, the clerid larvae will sometimes seize the offender but only one dipterous larva was attacked in this manner, and it was only partially consumed afterward. All of the clerid larvae were reared on Ips larvae so perhaps the reaction is more an acclimatization to a specific type of food rather than an inherited aversion. Some cannibalism was noted in the third and fourth instars when clerid larvae were overcrowded.

Enoclerus larvae move through the galleries with the head lowered and in a hypognathus position. When attacking its host, the predator thrusts the opened mandibles upwards, puncturing the ventral or lateral surface. The head is forced progressively farther into the victim, and the mandibles can be seen working in a raking fashion, forcing the body contents of the host towards the oral cavity of the predator. Clerid larvae have difficulty in successfully attacking unless the host is confined within a small space which allows the predator bracing and leaverage action. The third and fourth instars are unable to destroy adult bark-bettles unless the host is within the gallery.

Adults - A freshly cut lodgepole pine tree was kept under observation in the spring. Three weeks later Ips attacked this tree "en masse" in midafternoon of a warm sunny day. The following day a number of Enoclerus adults were observed moving over the bark, feeding heavily on the bark-beetles. Ips with only the posterior extruded from entry holes were commonly pulled out and consumed by the predator. During the short

period of several days before the attacking bark-beetles manage to establish themselves under the bark, they suffer considerable predation by adults of Enoclerus.

During this period females were observed laying eggs under bark scales. The males are very aggressive during mating, and several males may keep a female occupied for periods up to five minutes before she is able to escape. Oviposition was observed 4 to 5 minutes after copulation. Frequently the female moves about ejecting and retracting the ovipositor but laying no eggs, possibly seeking a satisfactory site. The number of eggs laid by a single female under natural conditions is not known. The largest number laid in a petri dish by a single female was 6.

Female Enoclerus kept under observation in petri dishes were reluctant to lay eggs, possibly due to the absence of essential environmental stimuli. After a period of several days to a week, females would deposit a few eggs at random over the bottom of the container or within folds of the cloth covering the bottom. In several cases, males consumed these eggs before they could be taken out.

The absence of adult Enoclerus from bark beetle infested slash is very noticeable once the adult bark beetles have moved into the subcortical regions thus becoming inaccessible. Within a week or so of the disappearance of adult bark beetles, there is little evidence of Enoclerus. The adult is rather timid showing some hesitation in attacking other organisms approaching it in size. Very slight disturbances will cause it to drop from slash to the duff.

It seems probable that most of the adult Enoclerus die of starvation, once the bark beetle adults are no longer available. The larvae require an abundance of food and this can only be obtained in host galleries

containing an accessible and continuous source of immature forms. Only the bark beetles provide abundant and continuous food supply. In addition, the development of the predacious larvae must parallel closely the development of the host. It is essential that very young bark beetle larvae be available as food for the first instar Enoclerus larvae. Continuous oviposition on bark beetle infested slash throughout the summer would be of little significance in raising the predator population. Duff samples taken during the summer failed to produce adult Enoclerus, so it is unlikely that they go into a diapause to carry them over to the second flight of bark beetles.

HEMIPTERA

Adults and nymphs of a small bug, were found occasionally in the main galleries of Ips. This has been identified by Dr. B. P. Beirne of the Systematics Unit as probably Anthocoris musculus Fall.

Adults were observed feeding on bark-beetle eggs by forcing their proboscis through the plug of boring dust which separates the egg from the egg gallery. It appears to behave primarily as an egg predator, being unable to reach the larvae once they have moved from the egg nitche. Possibly these predators feed upon other small organisms in the main galleries of the bark-beetles.

ACARINA

The most important egg predator found within the experimental area was a minute white to transluscent mite. No identification is available on this species as yet. 1/

Adult mites are carried into the newly established bark beetle gallery, attached to the ventral surfaces of the adult beetle. Females

move into secondary galleries and force their way past the egg plug, attaching themselves to the bark-beetle egg and becomes immobile. The mite then begins to swell, and eggs become visible within its body. Up to a dozen eggs may be exuded while the female is expanding. Within several days, the female is completely spherical in shape, and many times its original size. The body is densely packed with eggs, clearly visible through the body wall. The female remains alive, but is completely immobile. ore eggs may be exuded but the bulk of the eggs are released when the body wall of the mite ruptures. The eggs remain partially contained within the egg sack formed by the carcass of the mite. Up to 30 eggs were counted in one egg mass.

Newly laid mite eggs hatched within seven days. The bark beetle eggs were attacked by the newly emerged mites. In a short time an egg was completely deflated. The young mites appear to move into the main galleries. No evidence could be found of any attack on bark bettle larvae.

Throughout the summer these mites are common within the main galleries, but their food during this period is not known.

When adult Ips begin moving under the bark, the mites attach themselves onto the beetles. They are found most commonly attached to the ventral surface at the junction between head and thorax, also around the base of the legs. The mites leave the gallery with the host and overwinter attached to the host in the duff.

The following spring the cycle is repeated.

1/ This mite was identified by Dr. Nesbitt as "Pygmephorus sp."

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